Indian Munitions Board

Industrial Handbook

1919

Revised Edition

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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PREFACE.

MUNITIONS for a modern army cover practically all the wants of a civil community, *plus* the special arms, or lethal munitions, employed by the soldier in actual fighting operations. The scale of operations in a modern campaign is such that the wants of the army in the field necessarily compete with the requirements of the residual civil community which, in India, far outnumbers those on "active" service.

Thus, the duty of equipping the armies in the field brings the department of Government that is directly responsible for this duty into immediate touch with the industrial life of the country, not the manufacturing and producing section only, but the consuming section of the community also.

India, with its wealth in raw materials, has found it in the past easier to buy than to manufacture the articles required for its amenities of life. The war has shown, however, that it is desirable to be less dependent on European countries for manufactured goods, and India, like other countries, has been compelled during the last four years to improvise for the time being, while laying plans for industrial development in the future.

This handbook was originally prepared as a companion to the exhibit made by the Indian Munitions Board at the Exhibitions held in Bombay and Madras in the cold weather of 1917-18. The first edition having become exhausted and the demand for it from the public being still insistent, the opportunity has been taken of revising the original articles and of adding others, but the handbook is still incomplete and makes no claim to be an industrial survey of India. It is primarily intended to explain something of what has been done to develop India's industrial resources for war purposes; but it also describes some of the general industrial development, which has taken place during, and on account of, the war, and discusses the possibility of further development in the future.

Some difficulty has been felt in describing the operations of the Board and its branches, because some of them have come to an end

and others, though now still in progress, are likely in the near future either to cease or to undergo considerable modifications. In order to avoid constant changes from the present to the past tense and *vice versâ*—changes which would not be intelligible to the reader and might cease to be accurate by the time the book appeared or soon after—these descriptions have been uniformly couched in the past tense.

Many of the articles appearing in the handbook are written by authorities, who are not under the administrative control of the Indian Munitions Board, but have voluntarily contributed their information in order to make the handbook more useful. To them and to all who have assisted in its preparation the Board is greatly indebted. The opinions expressed in the signed articles are sometimes somewhat divergent and must be taken as expressive of their author's views. The Board considers, however, that advantage is gained by allowing authors to express, in their own way, views on questions about which there is room for more than one opinion at the present stage of development.

DELHI;
The 24th March 1919.

T. H. HOLLAND,
President, Indian Munitions Board.

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History and Organisation of the Board.

History.

In December 1916 an inquiry was initiated by His Excellency the Commander-in-Chief, as to whether more could not be done to develop Indian resources for war purposes, so as to relieve the United Kingdom as far as possible from the necessity of meeting extraneous demands. With this object and with a view to prevent competition and overlapping in the purchase of supplies, His Excellency suggested the creation of an organisation on somewhat similar lines to those of the Ministry of Munitions in Great Britain. The idea was approved by the Government of India and it was decided that as the new department would have the opportunity by its work of gauging the resources of the country, it should also undertake the duty of dealing with applications for the grant of priority assistance in the manufacture and export of articles from the United Kingdom to India.

While the steps to carry this decision into effect were under discussion, a telegram was received on February 1st, 1917, from the Secretary of State in which His Majesty's Government expressed their desire that further efforts should be made to develop Indian resources for the supply of the forces in India, Mesopotamia and Egypt. A few days later, on February 16th, 1917, the establishment of the Indian Munitions Board was sanctioned, which, after a period devoted to preliminary organisation, undertook its formal duties as a department of the Government of India under the immediate charge of His Excellency the Army Member on April 1st, 1917.

Functions of the Board.

The Board's primary function was the utilisation to the utmost extent of Indian resources in materials of all kinds (except food and fodder) required for the prosecution of the war, an object which included, not merely the actual use, wherever possible, of Indian materials and Indian manufactures, but also the purchase of these and of imported stores on the most advantageous terms by a purchasing organisation, which should eliminate competition in buying between the different departments of the public service. The Board had to meet civil as well as military demands for stores and became responsible for regulating the demands of India on the United Kingdom for plant and stores manufactured in England, where all available materials and expert labour were required for the task of supplying the needs of the armies in the European fields.

Early organisation.

As the Board was organised under war conditions, it was essential to cause as little dislocation as possible among the existing agencies which were supplying war stores. Its development, therefore, though in many ways rapid, was gradual and in accordance with the plan originally designed. The first step was to take over from the departments already administering them any existing supplying agencies which could both readily be detached and could more appropriately be placed under the Board's direction. But no effort was made to make changes for the sake of completeness, and thus the Board refrained from absorbing units which were already organised for war purposes in a self-contained manner, and did not in their operations conflict with other agencies. Thus, the arrangements made by the Commerce and Industry Department for the supply of mica, wolfram and lac were not disturbed.

The first branch organised was the Intelligence Branch on March 17th, 1917, and a few days later the Board took over from the Railway Board the provision of railway materials for overseas and the construction and supply of rivercraft, launches, etc., for Mesopotamia and other theatres of the war. These constituted two branches, the former of which also controlled the supply of steel from the Tata Iron and Steel Works. On April 1st the Hides Branch was formed in order to take over the purchase of raw and tanned hides for the War Office and at first, also, that of Tibetan wool for use for Government purposes in Indian mills. On April 12th the Priority and Home Indents Branches came into

being for the reasons already described, and on April 16th, a new branch was created under the name of Timber Supplies, to deal with the supply of timber and forest produce to officers indenting from overseas and in India. On May 31st the Indian Indents Branch was constituted to deal with all demands on India for the supply of stores, except for textiles for which a special branch was formed on June 19th. The Board had now reached a stage of development which absorbed all its energies for some time and no further branches were formed till January 1st, 1918, when the undertaking of the Ordnance Factory extension scheme, initiated by Sir Frederick Black of the Ministry of Munitions, necessitated the taking over of the Ordnance Factories from the Director General of Ordnance. Subsequently a number of new branches were formed as necessity arose, and the final organisation of the Board was as described below.

Final organisation.

The position of the Indian Munitions Board in the machinery of Government was analogous to that of the Railway Board, constituting, with the Army Member, a Department of the Government of India. It consisted of a President, assisted and advised by four Members. Unlike the Railway Board, however, the Indian Munitions Board had a Financial Member, who was also Financial Adviser in the Army Department, and referred direct to the Finance Member all questions of expenditure which required his orders.

The Board had an organisation at the head-quarters of the Government of India, which was supplemented by provincial organisations in each province. The head-quarters staff was divided into well-defined branches, each relating to a subject which, for technical or commercial reasons, required centralised control. Six of these branches were, however, stationed at Calcutta, namely Hides, Jute Manufactures, Shipbuilding, Electrical and Mechanical, Hardware, and Miscellaneous Branches and one, Agricultural Requirements, Mesopotamia, at Poona. Each branch thus constituted was placed under the administration of a Controller who was either an expert or, if chosen rather for administrative ability, was furnished with the necessary technical assistance. The Controllers were assisted as a rule by Deputy and Assistant Controllers, some of whom were stationed at important centres elsewhere in India, and each Member of the Board was directly responsible for a group of Controllers. Eventually, in addition to the branches which were specifically concerned with establishment and general

administrative work, there were twenty branches under Controllers which dealt with the following subjects :—

Headquarters branches.

(1) and (2) *Industrial Intelligence, and Chemical and Mineral Branches.*—The Industrial Intelligence Branch collected industrial information and disseminated it to other branches, to provincial Controllers and departments of industries, and thus acted as a general clearing house of industrial information. It worked in conjunction with other branches in developing Indian industries and resources and placed its information freely at the disposal of manufacturing firms. It also dealt with those industrial activities, such as the glass and pottery industries, which were not the special concern of other branches of the Board. A second branch, under the same Controller, dealt with the organisation of chemical research in India and such questions affecting the chemical and mineral industries as did not fall within the special sphere of the Director of the Geological Survey of India. The work done by this branch is briefly described in the next article.

(3) and (4) *Priority and Home Indents Branches.*—These two branches were created as the Indian agency of the Priority Branch of the British Ministry of Munitions. The Priority Branch controlled all priority organisations dealing with applications for priority assistance for materials required from the United Kingdom and the United States of America. The Home Indents Branch scrutinised all indents from Government Departments and Railways for articles required from the United Kingdom and also controlled applications for permits to export articles on the prohibited list, and both branches co-operated with other branches in dealing with demands received from indenting officers in India or overseas, and with the Munitions Manufactures, Intelligence, and Chemical and Mineral branches in the development of Indian industries. The manner in which they effected this is described in a subsequent article.

(5) *Indent Distribution Branch.*—The Controller divided all demands received by the Board among the appropriate supplying branches and dealt with all special cases regarding supply of stores which necessitated inquiries at the Board's headquarters.

(6) *Railway Materials Branch.*—This was formed to deal with the provision of railway materials, such as rails and fastenings, sleepers, bridging material, rolling stock, etc., to war areas, and also the control of the supply of steel from the Tata Iron and Steel Works, Sakchi, by an arrangement under which the Government

had first call on its entire output of steel. The rolling stock supplied from India to overseas forces has been drawn entirely from Indian railways. The assistance thus rendered by the railway organisations of India has been vital, but the depletion of rolling stock and material thus caused has added considerably to the difficulty of mobilizing the resources of India for the war.

(7) *Shipbuilding Branch.*—A separate account of this branch is given elsewhere by the Controller. As the Rivercraft Branch, it controlled the construction and supply of new rivercraft, launches, etc., and connected material for Mesopotamia and other theatres of the war, and also of new craft for coastal defence purposes. Subsequently its energies were largely devoted to the development of merchant shipbuilding in India. Repairs to inland and sea-going vessels were also controlled by it.

(8) *Timber Supplies Branch.*—This branch was created to deal with the supply of timber and other forest produce to indenting officers both overseas and in India. An account of its operations is given separately.

(9) *Hides Branch.*—The Controller of this branch directed the purchase of tanned and raw hides for the War Office and at one time also controlled that of Tibetan wool for use for Government purposes in Indian mills. He also exercised a general control over tanning in India under the Defence of India (Tanning) Rules. A description of his work will be found later.

(10) *Textiles Branch.*—This branch was formed to control the purchase in India of all textiles composed of cotton, wool or silk for Government service and of boots for the army. It originally controlled also the Army Clothing factories, which were taken over, on the 20th August 1917, from the Quartermaster General in India, but these were subsequently transferred to the new Clothing Branch.

(11) *Clothing Branch.*—As the work of the Textiles Branch admitted of sub-division into two distinct sections, a new branch was created to deal with all questions connected with the manufacture and supply of articles of clothing and the administration of the Army Clothing factories, the Textiles Branch retaining control of the purchase in India of textiles required for the purpose.

(12) *Jute Manufactures Branch.*—All demands for jute and kindred fabrics, such as *sunn* hemp, were met by this branch, whether

for India and the armies based on this country or for the Allies and British Possessions.

(13) *Agricultural Requirements, Mesopotamia, Branch.*—The Controller, with headquarters at Poona, supplied all agricultural requirements such as seed, irrigating plant, etc., for Mesopotamia, in consultation with the Central Transport and Foodstuffs Board and the Quartermaster General in India.

(14) *Ordnance Factories Branch.*—This branch was formed to enable the Board to administer the Ordnance Factories and their extensions.

(15) *Electrical and Mechanical Branch.*—The Controller met indents for electric plant, workshop machinery and engineering plant of all descriptions.

(16) *Hardware and Metals Branch.*—All hardware, tools and metals were purchased and supplied by this branch.

(17) *Oils and Paints Branch.*—This branch met all indents for oils, paints, rosin, tar, turpentine and varnishes.

(18) *Miscellaneous Stores Branch.*—The Controller supplied all miscellaneous stores, such as cement, brushware, cutlery, glass, soap, etc., not supplied by the other three branches named above.

(19) *Munitions Manufacture Branch.*—This branch was formed with the object of more fully utilising the workshop resources of India, more especially for ordnance stores other than those manufactured in Government factories. Orders were distributed so as to enable certain firms to specialise in particular classes of work, and it was hoped, had the war continued, that under these conditions the regulation of prices would have become practicable in the case of articles, for which there was a considerable demand.

(20) *Finance Branch.*—This branch was in charge of the Deputy Controller of War Accounts, who acted as the financial officer of the Board under the control of the Financial Member. He also acted as a Deputy to the Financial Adviser, Military Finance, and in this capacity, dealt with all questions involving sanction of expenditure. As an accounts officer, he was a Deputy of the Controller of War Accounts. The other officers of this branch were disbursing and audit officers under the supervision of the Controller of War Accounts.

Provincial organisation.

The provincial organisations included ten Controllers, provided, where necessary, with deputies and assistants, in each of the following areas :—

Bombay,	United Provinces,
Bengal and Assam,	Central Provinces and Berar,
Madras,	Bihar and Orissa,
Burma,	Delhi and
Punjab,	Karachi.

The provincial Controllers who were in most cases the provincial Directors of Industries, where such had been appointed, may be described as the liaison officers of the Board with the provincial Governments. They provided an easy and informal means of communication with each province and during the period of active hostilities not only acted as the executive officers of the Board in applying the Defence of India Rules, when necessary, and in the general superintendence of the subordinate establishments working in their areas, but saw that all local industries were fully utilised for war work; they also collected and supplied to the Board and its specialised Controllers all information required in connection with the Board's operations. This system of local representatives was later extended to the Indian States, which, since the foundation of the Board,

Indian States.

had been rendering assistance in various ways, especially in respect of timber supplies and the production of hides and leather. No systematic relations were, however, established until the Delhi Conference of May 1918, as the result of which Controllers of Munitions were appointed in Baroda, Mysore, Travancore, Benares, Kashmir, Pudukkottai, Banganapalle, Sandur, Hyderabad and Rampur. These appointments resulted in renewed offers of assistance and the supply of detailed information regarding the resources of the States concerned.

Defence of India Rules.

One of the most important of the functions of the Board was the utilisation of the Defence of India Rules for the purpose of securing munitions of war and facilitating the development of the resources of India. The principal rules which the Board found it necessary to use were Nos. 11A and 11AA, which provide for the collection of information regarding, and the acquisition of, stocks of articles required for war purposes. The Board resorted to the practice of requisitioning of goods only in those cases in which they could not be obtained at reasonable prices by private negotiation. Rule 11D, which provided

for the utilisation of any mine, industrial concern, or business for purposes connected with the prosecution of the war, was used principally to ensure the development of the tanning industry with a view to the supply of leather for army purposes. Rule 11G, which made provision for the control of dealings in war material, was for a long time utilised only to a comparatively small extent, principally in connection with steel plates and sections, which were required for ship repairs, it being essential that stocks of these should be conserved for this important purpose. But latterly the same rule was used to control dealings in general in steel plates, steel wire ropes and a few other articles needed by essential industries, but not manufactured in India and only available in very limited quantities. In exercising these powers every effort was made to avoid interference with reasonable trade requirements, and although delegations were necessarily made to subordinate officers, detailed instructions were given, the observance of which would prevent any avoidable inconvenience to the public.

On the whole, in consequence of the ready co-operation especially of the larger manufacturing concerns, very little use of the rules was necessary, and there was a general and gratifying response by both manufacturers and dealers in meeting war demands.

Purchase for stock.

The desire to supply the forces based on India from this country, and so to avoid unnecessary demands on the United Kingdom, naturally led to the decrease in stocks of all kinds of imported articles and, in the case of most of them, to great and irregular increases in price. To mitigate this cause of inconvenience, the Board, as described in a separate article, did its best to increase the manufacturing resources of India, and eventually in order to facilitate compliance with demands and to avoid disturbance of the market caused by emergent buying, made arrangements for the establishment of depôts at Calcutta and Bombay for stocks of articles most in demand.

Relations to Indigenous Industries.

The functions of the Indian Munitions Board as laid down in the *Gazette of India*, in February 1917, were :—" to control and develop Indian resources, with special reference to the needs created by the war . . . . to limit and co-ordinate demands for articles not manufactured or produced in India and to apply the manufacturing resources of India to war purposes with the special object of reducing demands on shipping." The ability of the Board to develop industries in India therefore has been strictly limited by the concentration of its energies on its primary object, namely, the immediate supply of demands from the armies in the Eastern theatres of war, but within those limits it has been able to foster the growth of indigenous industries in many ways, the most important of which are :—

(1) the direct purchase in India of articles and materials of all kinds needed for the army and civil departments and the railways ;

(2) the diversion, whenever practicable, by means of the priority system and its control over home indents, of all orders for articles and material from the United Kingdom and elsewhere to manufacturers in India ;

(3) the giving of assistance to individuals and firms who desired to import plant or to engage chemical and technical experts and skilled labour from Home or elsewhere, in order to establish new industries or develop old ones ;

(4) the dissemination of information and expert advice and the giving of other direct or indirect encouragement to persons prepared to establish new industries in India.

With the exception of foodstuffs, medical stores, and certain technical stores, such as mechanical transport, for the provision of which there already existed special organisations, the Indian Munitions Board became responsible for the supply of all articles required by the armies stationed in and based on India, by Government departments and by State railways, as well as for certain materials needed

by the Imperial Government at Home. The following statement shows the total amount expended in India through the agency of the Board during the year 1917-18, and the first six months of 1918-19:

TABLE.— *of the Indian Munitions Board for the eighteen months ending September 30th 1918.*

(Thousands of rupees.)

HEAD.	Year ending March 31st 1918.	Six months ending September 30th 1918	TOTAL EXPENDITURE.	REMARKS.
I. Salaries, establishments, etc :—				
(1) Headquarters .	7,79	8,14	15,93	
(2) Provincial . .	9,85	19,32	29,17	Does not include the cost of establishment for tanneries and factories which is taken under Head III.
TOTAL I .	17,64	27,46	45,10	
II. Supplies :—				
(a) Shipbuilding, etc.	1,50,97	75,70	2,26,67	
(b) Tata's rails and fishplates.	1,05,16	28,68	1,33,84	
(c) Other railway materials, including sleepers.	1,46,82	1,45,92	2,92,74	
(d) Timber . .	86,36	1,34,82	2,21,18	
(e) Engineering stores	6,04	45,27	51,31	
(f) Textiles and jute	85,50	78,91	1,64,41	Mainly for jute manufactures : does not include payments on account of the Army Clothing Department which are taken to Head III (a).
(g) Ordnance and miscellaneous stores.	2,54,77	7,37,63	9,92,40	Does not include payments on account of the Indian Ordnance Factories, which are taken to Head III (b). Tents, packing materials and leather articles are the chief items of expenditure under this head.
TOTAL II .	8,35,62	12,46,93	20,82,55	

TABLE.—*Expenditure of the Indian Munitions Board for the eighteen months ending September 30th 1918*—contd.

(Thousands of rupees.)

HEAD.	Year ending March 31st 1918.	Six months ending September 30th 1918.	TOTAL EXPENDITURE.	REMARKS.
III. Factories etc.—				
(*a*) Army Clothing Factories.	3,87,67	5,75,34	9,63,01	
(*b*) Ordnance Factories.	67,74	2,42,64	3,10,38	
(*c*) Tanneries and tanstuffs.	15,35	8,14	23,49	
(*d*) Other factories .	9,15	7,25	16,40	
TOTAL III .	4,79,91	8,33,37	13,13,28	
IV Miscellaneous . .	3,02	..	3,02	
GRAND TOTAL .	13,36,19	21,07,76	34,43,95	

Effects of purchases by the Board.

This statement does not include stores purchased from abroad, and although many of the articles which were purchased in India were imported, the tendency was to rely more and more on local manufacture, for the development of which for war purposes the Board was partly brought into existence. The Board's invariable policy was to deal with manufacturers direct, wherever possible. An analysis of eight and a quarter crores expended on ordinary stores during the last quarter shows that 47 per cent. was paid to purely Indian firms, 26 per cent. to purely European firms and 27 per cent. to joint-stock companies. The joint-stock companies include the cotton mills, which are mainly Indian, and the jute mills, which are European in management but composite in shareholding. In addition to this, over a crore a month was paid for hides and leather, almost entirely to Indian firms. There is no doubt, therefore, that Indian firms have contributed mainly to the supply

of stores, while far the greater part of the money paid to European firms and joint-stock companies has necessarily stayed in the country. Thus the 34 crores paid out by the Board during the last eighteen months must have given some assistance to the development of industries in India. That this is so is clear from the accounts of the textile and timber trades, the tanning and leather industry, and the development of the Tata Iron and Steel Works given elsewhere in this book. The factories recently brought under the Board's own control, also, are by no means insignificant examples of manufacturing enterprise. The operations of the army clothing and leather factories are described separately, while the expansion in the output of the ordnance factories can best be seen from a comparison of their total cash expenditure in 1913-14, *viz.*, about fifty lakhs, with the sum of Rs. 2,42,64,000 which was spent on them in the first six months of this financial year. A large scheme for extension, which was undertaken on the advice of Sir Frederick Black of the Ministry of Munitions, is now being carried out at a cost of about three quarters of a million sterling. This with the new acetone factory at Nasik, will give employment to a number of Indians and render the country more nearly independent of outside supplies of military stores.

Priority procedure.

All indents from Government departments and railways passed through the Board and its local representatives, and were carefully scrutinized with a view to obtaining every article possible in India. As Government has the greatest spending power of any body in India, the effect of this alone in encouraging manufactures was very great. In order to economise freight and prevent unnecessary demands on the United Kingdom and the United States of America, recommendations for the grant of priority were made only when it was impossible to purchase the article or a suitable substitute locally, or to arrange for its manufacture within a reasonable period. Openings which came to light in this way were brought to the notice of likely firms, with the result that many new branches of manufacture are being and have been started in India. In numerous cases, also, the Board was able to bring the names of existing manufacturers, of which it became aware through its Intelligence Branch, to the knowledge of customers and thus assisted in the development of industries. The following list of articles among others for which the Board repeatedly refused to recommend priority, on the ground that they, or a suitable

of stores, while far the greater part of the money paid to European firms and joint-stock companies has necessarily stayed in the country. Thus the 34 crores paid out by the Board during the last eighteen months must have given some assistance to the development of industries in India. That this is so is clear from the accounts of the textile and timber trades, the tanning and leather industry, and the development of the Tata Iron and Steel Works given elsewhere in this book. The factories recently brought under the Board's own control, also, are by no means insignificant examples of manufacturing enterprise. The operations of the army clothing and leather factories are described separately, while the expansion in the output of the ordnance factories can best be seen from a comparison of their total cash expenditure in 1913-14, *viz.*, about fifty lakhs, with the sum of Rs. 2,42,64,000 which was spent on them in the first six months of this financial year. A large scheme for extension, which was undertaken on the advice of Sir Frederick Black of the Ministry of Munitions, is now being carried out at a cost of about three quarters of a million sterling. This with the new acetone factory at Nasik, will give employment to a number of Indians and render the country more nearly independent of outside supplies of military stores.

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All indents from Government departments and railways passed through the Board and its local representatives, and were carefully scrutinized with a view to obtaining every article possible in India. As Government has the greatest spending power of any body in India, the effect of this alone in encouraging manufactures was very great. In order to economise freight and prevent unnecessary demands on the United Kingdom and the United States of America, recommendations for the grant of priority were made only when it was impossible to purchase the article or a suitable substitute locally, or to arrange for its manufacture within a reasonable period. Openings which came to light in this way were brought to the notice of likely firms, with the result that many new branches of manufacture are being and have been started in India. In numerous cases, also, the Board was able to bring the names of existing manufacturers, of which it became aware through its Intelligence Branch, to the knowledge of customers and thus assisted in the development of industries. The following list of articles among others for which the Board repeatedly refused to recommend priority, on the ground that they, or a suitable

substitute, could be manufactured in India, show what opportunities have been afforded to Indian manufacturers by the war: carbolic, sulphuric, and hydrochloric acids, caustic soda, magnesium chloride, zinc chloride, filter-bag sheaths, brushes and brooms of all kinds, leather and cotton beltings, boiler composition, bolts, nuts and rivets, locks and padlocks, galvanised buckets, buttons, buffer straps and buffers, buffalo jute-pickers, cast-iron piping, lamp chimneys and globes, chrome leather, disinfecting fluids, fire-bricks, soldering fluid, glass dishes and jars, various surgical instruments, pen-knives and pruning knives, scissors, leather washers and other miscellaneous leather articles, linseed oil, lubricants, manilla rope, antifriction metal, metal polish, red and yellow ochres, turpentine, paints and varnishes, roller skins, soap, tallow, tea chests and tea lead, twine, paraffin wax, cotton webbing, ship-fittings, sheepskins for rice mills, gears, cast-iron wheels, wooden handles for tools, hand tools and machinery spares of all descriptions.

In order to develop India's manufacturing capacity to the fullest possible extent, the Board appointed an experienced engineer as Controller of Munition Manufactures, whose particular duty it was to encourage the manufacture in India of articles required for the prosecution of the war. A special branch, the operations of which are described elsewhere, was also constituted to supervise the construction and re-erection of rivercraft, launches, etc., and to assist in the development of merchant ship-building in India. Apart from this, the Board supported applications for the export of plant from the United Kingdom and elsewhere in all cases in which it was required for the manufacture in India of essential articles which were likely to be produced during the period of the war. In similar cases the Secretary of State was frequently asked to support applications for passports for chemical and technical experts and skilled workmen required from Home.

The Intelligence Branch.

The Board has also maintained an Intelligence Branch, the function of which was to collect industrial information and disseminate it to other branches, and to provincial Controllers and Directors of Industries and so to act as a general 'clearing house' of industrial information. It worked in conjunction with other branches in developing Indian industries and resources, and its information was placed freely at the disposal of manufacturing firms and all concerns or persons, who seemed likely to undertake the manufacture of any useful article,

Chemical industries.

Special attention has been paid to the development of chemical industries in India, on the existence of which depends the possibility of the sound growth of indigenous industries. The Board maintained a permanent chemical adviser, whose expert knowledge was at the disposal of all inquirers. A conference of chemists was held at Lahore in January 1918, in order to discuss how far it was possible in present circumstances to utilise the services of chemists in India to carry on investigations of war importance or connected with industrial development, and in what way chemical research should be organised after the war. As a result of this conference, a number of researches have been conducted under the auspices of the Board by chemists, who kindly placed their spare time at its disposal, and from these researches some important results have been obtained. Constant inquiries have also been made as to the development of chemical manufacture in India and every possible assistance and encouragement has been given to firms engaged in this work. The following important chemicals among others have been produced on a commercial scale for the first time in India since the war began :—Caustic soda, magnesium chloride, red lead, thymol, sandalwood oil, and zinc chloride. The manufacture of sulphuric acid, copperas and other chemicals has also been greatly developed.

In the cold weather of 1917-18, a small exhibit was organised in connection with the exhibitions of foodstuffs, etc., held in Bombay and Madras. In order to explain this exhibit and also to show what was being done in the way of industrial development, the first edition of this handbook was prepared. Both the exhibit and the handbook were prepared at short notice and so were not fully representative of the developments that have recently occurred. It is the intention of the Board to publish a number of special monographs on various industries, such as the textile and tanning industries, showing their previous history and development during the war and their future prospects.

Other industrial development.

The Board has paid special attention to the development of what may be called "key" industries, so far as this has been possible in India. For instance, attention has been focussed on the accessories used by the milling industries in this country, such as roller skins, pickers, sheep skins for rice polishing, belting, etc. Several of these articles are now being manufactured with success in India, and some

of our most important manufacturing industries are less liable to be disturbed by a sudden cessation of imports than they were before the war. Other industries, to which considerable attention has been paid, are the manufacture of anti-friction metal, ferro-manganese, glass, pottery, refractory bricks, disinfecting fluids, tea-pruning knives, tea chests, asbestos boiler composition, glucose, coir articles and graphite crucibles. In most of these, considerable success has now been obtained by manufacturers. Ferro-manganese is now exported on a large scale. The development of the glass industry has already been considerable, and such articles as bottles and phials, which were previously imported entirely from abroad, are now being manufactured in the country on a commercial scale. Refractory materials, suitable for lining the hottest furnaces, are now made in India, and it is hoped that the country will soon be independent of foreign imports of these articles. Pruning knives are also being made in numbers practically sufficient to supply the whole demands of the tea industry, which requires several hundred thousand annually.

The Board has also examined the possibility of the manufacture of certain important articles on a large scale in India. An example of this is the inquiry into the possibility of producing calcium carbide and nitrogen products, which is briefly discussed elsewhere. It is hoped that these and other researches will lead eventually to the establishment of various basic industries in India, which will hasten the general industrial development of the country. Numerous schemes for the establishment of useful industries in India have been placed before the Board. These owe their inception chiefly to the enterprise and initiative of private firms. The following examples of new manufacturing industries, for which in many cases the plans are already far advanced, may be given:—

- the distillation of coal tar;
- the rolling of steel plates and the making of galvanised sheets and tin plates;
- the refining of copper and zinc;
- the erection of plants for making steel tubes and steel piles;
- the manufacture of textile and agricultural machinery;
- the making of railway wagons and electrical plant;
- the production of steel-wire, cutlery and enamelware; and
- the construction of electric furnaces for the production of steel castings and ferro-alloys.

Development during the war has, however, been hindered by several causes, which have made it far more difficult for India than for other countries more advanced industrially to take advantage of the opportunities afforded by the war. These are —

(*a*) the great difficulty under war conditions of obtaining essential machinery and materials such as cannot be made in India ;

(*b*) the shortage of coal and coking plant, coupled with a shortage of railway wagons and coasting vessels ;

(*c*) the difficulty of procuring from abroad chemical and technical experts, who are all needed in their own countries (India herself has very few such experts) ; and

(*d*) the shortage of skilled labour.

Industrial Development in Bengal.

By J. C. K. Peterson, C.I.E., I.C.S.,
Controller of Munitions and Director of Industries, Bengal.

Dependence of industries on imported accessories.

The war has already had a very direct effect on all industry in India. It has taught India its dependence on other countries and the danger of such dependence.

The two chief industries in Bengal, jute and tea, were entirely dependent on supplies of machinery from Europe. At the outbreak of war, if the supply of raw hide pickers from England had stopped, most of the jute mills on the Hooghly would have had to shut down. The consumption in the Bengal jute mills is approximately 45,000 a month. If pickers could not have been obtained, machinery and buildings worth millions of pounds sterling would have lain idle.

A very large proportion of the Indian tea crop was, and still is, packed in boxes obtained from foreign countries. Patent chests were imported from Russia or Japan, and the metal fittings came from England or America. Ordinary boxes are also imported from Japan in large quantities. Hoop iron, nails and clips for fastening the patent chests also come from foreign countries. Without these supplies it would be impossible to pack the tea and a very large percentage of the crop would rot, as tea cannot be stored in bulk.

These are only minor instances, but they indicate the danger to India of dependence upon external supplies.

Industrial development : its causes and character.

The industrial development in Bengal which has followed on the war has run mostly on this line. A need has arisen; some source of supply has been cut off, and immediately private enterprise assisted or directed by the State, has come forward with attempts to replace it. Military necessity drove the State into the great markets. The State became a shopkeeper on the largest possible scale, and it could not afford to risk any shortage in supply. The old theory that private industry should be left to look after

itself is dying. In war time, industry cannot look after itself. The cutting off of supplies has, therefore, led to development along one line.

In another direction the cutting off of markets has led to development. This is not at present so much in the public notice, but eventually it will be a more far-reaching cause of industrial development than the other. One of India's most valuable possessions, both from a military and a commercial point of view, is a constant supply of raw hides and skins. Together with this, there is the very large supply of tanning materials, both vegetable and chemical, which exist in the country. The tanning of a hide adds roughly four to five rupees to its total value, yet for years India had been exporting its hides and its vegetable and chemical tanning materials in the same ships. A certain amount of tanning was carried on, both vegetable and chemical, but the number of hides treated was negligible compared with the number exported. In Bengal alone the raw hides exported in 1913-14 weighed 1,302,490 maunds. Of these hides the Central European Powers took the greater proportion. In fact it is estimated that before the war at least 60 per cent. of the total export of raw hides went either to Germany or Austria.

When war broke out this market vanished. The world, however, must have leather, and it is inconceivable that these enormous supplies of raw materials should be allowed to be wasted. The military value of constant supplies of leather may very easily be one of the determining factors in a war, for no army can fight without boots and harness, and the wastage in the field is enormous. The market formerly offered to India by the Central Powers was therefore largely replaced by England and her Allies, and large quantities of hides are now being exported for their armies. Already, however, it is said that England cannot tan the supply of hides which is being sent out of this country, and India is being asked to extend tanning in this country. The cutting off of the Central European markets has made this a practical necessity, and already private and public enterprise is meeting the necessity.

It is impossible to make any territorial division in dealing with the industries of this side of India. The centre of development is Calcutta. The large business firms have their headquarters here and the influence of Calcutta as a market, a port, and a clearing-house for ideas and schemes for development extends over the provinces of Bihar and Orissa, and Assam, as well as over Bengal.

The schemes mentioned below in some cases are being worked out in Bihar and Orissa and Assam as well as in Bengal. The reason is obvious. Bengal itself contains few natural resources, and its industries depend very largely on the great mineral deposits which exist all along its border in Hazaribagh, Palamau, Singhbhum, Manbhum, and the Feudatory States of Orissa and Chota Nagpore. It is therefore impossible to separate the subject territorially.

The present industrial development has already effected a great deal. The air is full of new schemes and the country of new enterprises, which are being rapidly developed to supply its wants. Public opinion is veering round from its former indifference or satisfaction to a discontent which means to see that India is in future self-supporting and that its commerce, trade, and industries shall no longer be dependent on external supplies. The material effects of these great causes can be traced in every industry in Bengal.

Hides and tanning.

In 1913-14 the weight of the raw hides exported from Bengal was, as has been said, 1,302,490 maunds. The weight of tanned hides exported was 13,153 maunds. It would not be supposed from these figures that Bengal had an inexhaustible supply of both vegetable and chemical tanning materials and that one of the first tanneries in India (John Teil & Co.) was originally established in Calcutta. It was argued that the water of Calcutta was not suitable for tanning, that tanning material could not be obtained, that the climate made tanning impossible. All these and other reasons were put forward as causes for the apathy displayed towards this very important industry. As a direct result of the war these assertions have been examined both by private enterprise and by Government. The water has been analysed and found quite suitable, as indeed the experience of the small tanneries which already existed had proved.

New processes of chemical tannage are being examined. There are already two chrome tanneries in Bengal, the Berhampore Tannery and the National Tannery. One tannery in Calcutta (the National Tannery) is already making its own chromate salts from the raw ore obtained from mines in the Singhbhum district. In Calcutta Messrs. Graham & Co. are considering the possibilities of a new process which will greatly shorten the period of tanning.

Leather manufactures.

In the manufacture of leather goods there has also been great development. The demands from the jute mills for the leather articles which they require

have helped to produce this. Raw hide pickers are being made by Messrs. Graham & Co., and the Berhampore Tannery (Chari & Co.). Roller skins, picking bands and picking straps are being made by the Berhampore Tannery, the National Tannery and other tanneries. Leather belting is being made by the Albion Tannery, and proposals for the establishment of a factory for its manufacture have been taken up by another Calcutta firm. The mills have themselves discovered that country leather will serve for many purposes for which formerly imported leather was used. Leather on edge rollers have been made successfully and most of the mills are now using rollers with country leather laid on flat.

Very large quantities of leather are required for the army for harness and saddlery equipment, boots, and the *munda* shoes, which are used by the followers. There is also a large and constant demand for half tanned leather from the War Office in England. This trade in Bengal has now got a fair start and is fairly well organised. Previously most of the tanning done was in small tanneries which worked on insufficient capital. The tanners were therefore strongly tempted to remove the hides from the tanning pits before they were properly tanned, in order to turn over their capital more rapidly. The result was that the tanning in Calcutta was inferior. The standard has now been raised and a very large amount of capital has been brought into the business by the large firms who have taken it up. Messrs. Sassoon & Co., and Messrs. Graham & Co. have constructed new tanneries, the total output of which, when they are in full swing, will be approximately 50,000 hides a month. Two existing tanneries have been taken over by Messrs. Bird & Co., and Messrs. Grace Bros., respectively, and are being re-constructed.

In order to assist and guide this new industry the Government of Bengal have approved a scheme for the institution of a Research Tannery in Calcutta. The scheme has now been worked out in detail. A site has been selected and has been acquired, and the buildings are practically completed. An Indian student who has been doing special research work in England has been appointed as chemist. The special programme of work which has been laid down for the tannery is :—

(1) to investigate local tan stuffs and their value;

(2) to investigate the possibility of cultivating *tarwad*, *karwa* and any other tan stuffs in this province;

(3) to investigate sole leather tannages;
(4) to arrange for a clear statement and classification of the Indian hides coming into the Calcutta market;
(5) to experiment with chemical tannages.

The manufacture of tea chests, machinery, tools, etc.

Apart from the machinery used, which is almost entirely imported, the tea industry also depends very largely on imported consumable stores. The total number of tea chests required for the Indian crop is between three and four millions. Of this number not more than one and a half million were, before the war, manufactured in the country. The chief reason for this was that exporters greatly preferred the patent chests either of three-ply wood (as the Venesta and Acme chests), or of metal (as the Metallite chest), because these chests weighed less, were more easily closed, and would hold more tea. With high freight the advantage of a light box is obvious and the big Russian buyers would not export except in patent chests. High railway freights, also, were against the Indian saw mills competing successfully with Japan and other countries in the supply of ordinary wood chests, and, except in Assam, where local boxes were largely used, the possibilities of an Indian supply had been hardly examined. The timber required for tea chests is of a very special kind. It must contain no sap which would corrode the lead in which the tea is packed, must be free from any odour, as tea will take this up readily, and must be well seasoned, as the tea is usually hot when packed and unseasoned wood warps. An examination of the question has shown, however, that suitable timber exists in India in large quantities and that it is only necessary to put the producer and consumer in touch with one another to secure its acceptance. In addition, the demand for patent tea chests will inevitably drive this country to establish three-ply factories for the manufacture of these. Messrs. Bird & Co. have already established a three-ply factory in the Surma Valley in Assam, and Messrs. Davenport & Co. have obtained a concession in the forests of Northern Bengal with the object of supplying the demand for three-ply tea chests in this province. With this project this firm is associating a lead rolling mill.

Other needs of the industry are already pressing on the Indian producer. Tea lead is required for packing. This is already produced in Bengal (the Kamarhatty Lead Mills) and also in Ceylon, from Burmese lead, but the supply is not sufficient for the entire Indian crop and other proposals have been put forward for the

establishment of new mills which will make India entirely self-supporting in this respect.

The tools and implements required by the tea industry are also now being manufactured in India. The attention of Government was first directed to the manufacture of pruning knives. Very large quantities of these are used by the tea industry amounting, it is computed, to about two lakhs a year. In a very short time the manufacture of these from English steel was taken up in India and Messrs. Skippers & Co., and other firms are now making good knives in this province. Pruning knives are also being made by Aspinwall & Co., in Southern India, Johnson & Co., of Aligarh and by local blacksmiths and manufacturers in Darjeeling, Manbhum, and Shillong. Some of these local products are quite satisfactory and the makers do a fairly large local trade in them. One of the chief difficulties is the supply of steel. The knives can be made but there is a great shortage of suitable steel and makers are experiencing difficulty in obtaining supplies. It has, however, been ascertained that the Tata Iron and Steel Works can produce steel of the quality required. The first knife made from their steel was produced by Butto Kristo Paul & Co., Calcutta, and as a result of the experiment Tatas have offered to supply steel of the quality required. Firms are also taking up the manufacture of the hoes, digging forks, kodalis, etc., required by the tea industry.

The only other plant required by the industry is the machinery actually used in the manufacture of tea. With very few exceptions this has never been made in the country. Messrs. Marshall & Sons of Gainsborough, England, have now however decided to establish a branch in India, where they propose to make and repair most of the machinery required by the industry. The machinery used in the manufacture of tea is very intricate and can probably only be made by a firm that has always made a speciality of it. In addition to this, many engineering firms are now repairing tea machinery or making spare parts which have never before been made in this country.

Engineering, etc.

In the engineering industry there has naturally been great development. One of the chief objects of enforcing the priority procedure was to save skilled labour in the United Kingdom, so that it might be concentrated on work essential to the war. As a result, India has been thrown more and more upon her own resources. Machinery which

formerly would have been discarded has been repaired and kept in work owing to the impossibility of obtaining replacements. Machines have been made in India which have never been made here before, as it is now impossible to obtain them elsewhere. Further, the constant demands made upon India by the armies in Mesopotamia and East Africa for munitions of every kind, from shells to rivets, bolts and nuts, have stimulated mechanical production very greatly and much ingenuity has been displayed in meeting these demands.

There has also been much direct development due to civil demands for materials and machinery which formerly were obtained from external sources of supply. Galvanising on a fairly large scale is now being done by P. N. Dutt & Co., and by the Indian Galvanising Company (Heatly & Gresham). Both these works existed before the war, but have developed greatly as the result of the demand for such galvanised articles as were formerly imported. Kilburn & Co., and Heatly & Gresham are installing plants for the manufacture of enamelled iron ware in India. Heatly & Gresham have also established a workshop for the manufacture of the vacuum brake material required by Indian Railways. Electrical and medical porcelain is being made at the Calcutta Pottery Works at Tangra. These works are now working practically at full pressure and most of their output is taken up by direct war orders. Messrs. Balmer, Lawrie & Co. are starting a workshop for the manufacture and repair of all classes of electrical machinery. Messrs. J. C. Bannerjee, J. C. Galstaun, McLeod & Co., and other firms are importing plants for the manufacture of bolts, nuts and rivets.

In the jute industry practically all the consumable stores and all the machinery were, before the war, imported from the United Kingdom. Bobbins, plane tree rollers, pickers, roller skins, belting, porcelain thread guides, etc., all came from England. Careful examination has shown that all these stores and many others can be successfully produced in this country, and they are now being produced successfully on a commercial scale. Bobbins of excellent quality are made by A. T. Mukherjee, while plane tree rollers have been made by Davenport & Co.'s saw mills in the south of India. Porcelain guides are made by the Calcutta Pottery Works.

One of the largest makers of textile machinery in the United Kingdom is considering a scheme for the establishment of a branch works in India for the manufacture of textile and especially jute

machinery. Messrs. McLeod & Co., at the Britannia Engineering Works, in addition to the manufacture of spare parts for jute and cotton mill machinery, have now obtained a complete plant for making spindles and flyers by the latest and most approved methods. They also do fine iron-and brass castings such as have hitherto been imported from England, and manufacture of malleable castings. McLeod & Co. are also considering a scheme for the manufacture of agricultural implements in India from Indian steel. All these industries are at present handicapped by the shortage of pig iron for ordinary industrial purposes and also by the restriction on the import of suitable machinery for new developments.

The Angus Co. has set up a very large mechanical workshop where they hope ultimately to be able to make all classes of jute mill machinery and all the consumable stores which are at present imported from England. Owing to the American capital invested in this company, it has been able to obtain large supplies of machine tools of the latest type from America and expert supervision for the proposed new works from the same country as well as supplies of raw material. The works are at present engaged in the manufacture of machine tools which they will themselves require, among which may be mentioned a seven-foot centre lathe.

The Bengal Brass Company manufactures all classes of brass and gun-metal work. This firm proposes to import a complete wire-drawing plant.

John King & Co. have made the following articles which were formerly imported:—Baling press complete with pumps working at a pressure of 2 tons per square inch as used in the jute mills, colliery coal-tub wheels, large double crank solid forged crank shafts, milling machines, lathes of all sizes, rag and milling machines for cloth, steam hammers, winding engines, and drying machines for roping. This firm is also experimenting in the manufacture of emery or carborundum grinding wheels. The workshops attached to the jute mills are also now manufacturing many articles which were formerly imported.

The urgent need for iron and steel in England, France and America for ship-building and to make good the wastage of modern war, at a very early stage, largely deprived India of external supplies of iron and steel. India was thrown on its own resources which are still insufficient to meet its demands. As a result it was necessary to organize the iron and steel trade to meet demands. The Tata

Iron & Steel Co. have undertaken very large extensions (see page 401). The Bengal Iron and Steel Company also propose to take up the manufacture of steel after the war at Kulti and, a more recent company, the Indian Iron and Steel Co. (Burn & Co., Managing Agents), will make pig iron and steel at Asansol.

There has also been much development in the manufacture of chemicals on the Hooghly in the neighbourhood of Calcutta, largely as a direct result of the war. Messrs. Andrew Yule & Co. have started the Great Indian Phosphate Co. and the Magadi Soda Co., for whom they are agents, have established large works at Budge Budge with a view to manufacture caustic soda from sodium carbonate imported from East Africa. Messrs. D. Waldie & Co. and the Lister Antiseptic Dressing Co. are distilling coal tar on a small scale. The Bengal Chemical and Pharmaceutical Works are making thymol from *ajwan* seed, refined saltpetre from the crude product of the Bihar factories and potassium carbonate from the same raw material, and surgical dressings. They are also at present manufacturing fire extinguishers. Messrs. Smith, Stanistreet & Co. have added largely to the number of locally made drugs and medicines, and the North-West Soap Co. is in a position to supply concentrated commercial glycerine, carbonate of potash and caustic soda. Messrs. Andrew Yule & Co. have installed a plant for the extraction of salt on a large scale. Development in the chemical industries is greatly retarded in many directions by the restrictions placed on the import of machinery and plant. The rise in the price of heavy chemicals and the difficulty in procuring the services of competent experts operate in the same direction and also preclude industries such as paper making, which were established long before the war, from taking all the advantage of the situation created by the war.

Another line of development is the manufacture of fire bricks and silica bricks. Supplies from abroad having been cut off, the maintenance of the steel and iron furnaces was imperilled and it was immediately necessary to organise the manufacture of the bricks required for the furnaces in this country. Fire bricks are now being made in very large quantities by Messrs. Andrew Yule, Messrs. Bird & Co., at Kumardhubi and by Messrs. Burn & Co. The entire output has been taken up by the Tata Iron and Steel Works for the maintenance of their furnaces.

Textiles.

In Bengal, attempts have been made to organise the hand-weavers, and for the manufacture of *dosuti* for tents, and tapes and *khaki* webbing are being manufactured by hand on a large scale in Calcutta and its neighbourhood, Howrah, Hooghly, Nadia and Bankura. Buttons are also being made for the army by the Home Industries Association and by other firms. Experiments are also being made in consultation with the Government Fibre Expert as to the use of *sunn* hemp as a substitute for flax, of which there is now a great shortage (see page 366.)

Industrial Development in the Madras Presidency.

By C. A. Innes, I.C.S.,
Director of Industries, Madras.

Before the war the chief imports into the Madras Presidency were almost entirely manufactured goods, and the chief exports consisted mainly of raw materials. Natural handicaps were largely responsible for this state of affairs, and it is not surprising that the past four years have not been marked by the development of new industries on the same scale as in Bengal. But the effect of the war has been felt in many ways. Generally speaking, it has tended to make the Presidency more self-supporting and less dependent on the United Kingdom, and while it has arrested temporarily the development of some industries, it has opened up new possibilities and has diverted energy into new channels.

The tanning industry: East India kips.

Before the war the most important industry in the Madras Presidency, judged by the test of export trade, was the tanning of hides and skins. The latter branch of the trade was exceptionally prosperous in the first two years of the war, and the high prices ruling for skins in England, the United States of America and Japan, led to a large increase in exports. But owing to the necessity of conserving bark for the tanning of hides required for the purposes of the War Office, it was found necessary to prohibit the tanning of skins in April 1917, and the tanneries are now either idle or are employed in the production of the rough tanned cow hides known as East India kips, which are in great demand for use in the manufacture of army boots. The development of this branch of the Madras tanning industry is dealt with in detail in another part of this volume,* and need not be referred to at length here. But it may be mentioned that not only has the production of kips been greatly increased, but the quality of the leather has been immensely improved by the control exercised by the Indian Munitions Board over the tanneries and by the prohibition of the pernicious practices of adulteration and

* See page 160.

excessive greasing. All branches of the trade are agreed that the prohibition of adulteration should be continued after the war, and the Government of Madras are now considering what measures should be taken to secure this end.

Tanning barks.

The great increase in the output of kips and skins in the first two years of the war led to an acute shortage of tanning bark, and steps have been taken not only to encourage the cultivation of *avaram* (*Cassia auriculata*), the tanstuff most commonly used in the Madras Presidency, but also to popularise the use of other tanning barks. Mr. Pilgrim, the Tannin Expert to the Government of India, toured in the Presidency in 1917 in order to investigate its resources in tanning materials, and on his advice a series of experiments with new tanstuffs, either by themselves or in different mixtures, was instituted at the Leather Trade School. Many of these experiments have been very successful, and as the result of them, the twig and trunk bark of *Anogeissus latifolia* and wattle bark have been issued to tanners by the Controller of Tanstuffs.

Finished leather.

The demand for leather accoutrements for the army and for certain classes of leather goods previously imported from home has also stimulated the production of finished leather in Madras. In addition to the Chrome Leather Company, two new leather firms, the Madras Leather Co., Ltd., and the South Indian Leather Co. have come into existence, since the war began, and gloves, leather waistcoats, bandolier pockets, harness and other items of military equipment are made in large quantities, as well as roller skins, leather belting and picking bands.

The weaving industry: Buckingham and Carnatic mills.

Most of the Madras weaving mills have been pressed into service for the supply of cloth required by the troops. The Buckingham and Carnatic Mills rendered the most important service in this connection, and used to supply monthly, approximately, the following quantities of materials :—

Khaki drill	1,500,000 yards.
Khaki *pagri* cloth	250,000
Doosootie (for tents)	90,000
Canvas duck (for nose bags, etc.)	40,000
Cotton holland (for lining)	30,000
Khaki tape 2"	50,000
Khaki webbing (for rifle slings)	25,000
Cord for identity discs	1,200 lbs

In order to obtain these results, however, the mills have had to provide substitutes for many essentials which hitherto they

have imported, and their record in this respect is an interesting example of the effect which the war has had in tending to make Indian industrial concerns less dependent on Europe. For the dyeing of fast khaki, for instance, chrome alum is necessary, and before the war this chemical was imported from Germany. On the outbreak of war, the mills thrown on their resources made chrome alum for themselves from bichromate of soda, and have also experimented in the manufacture of bichromate of soda. An experimental furnace has been erected, and attempts have been made to convert chromite, which is a mixture of chromium and iron oxides, first into sodium bichromate and then into chrome alum. Promising results have been obtained, but the matter is still in the experimental stage. Turkey red oil, which was formerly imported from the United Kingdom, is now made in the mills from indigenous castor oil and Indian-made sulphuric acid. Similarly the tarpaulins used for packing bales of cloth, which formerly were imported, are now made at the mills from Indian hessian cloths on a machine designed and built in the mill workshops. Machinery for dyeing khaki, rifle slings and tape has also been designed and made in the workshops as also webbing looms. Since the war started, it has been necessary to store large quantities of sulphuric acid in lead-lined tanks, and the mills now do their own autogenous soldering of the lead joints which formerly could be done only by European experts. Many other articles which formerly were imported are now made in the mill workshops, such as frames for healds, set screws, bolts and nuts, shoe rivets for baling, weft fork holders, box end spring bits and temple heads, all for looms, doffing cans, weft cans and oil cans, woven motor starter resistances, 3 pole switch gear in interlocked C. I. case and armature coils for D. C. motors. Picking sticks, staves and lease rods, shuttle pins, warpers creel pegs, dobby lattices and other wooden articles previously imported are now made from local timbers. One of the most interesting developments has been thread making. Owing to the demands of the Army Clothing Department at one stage of the war for locally-made thread, extensive experiments were made to produce thread from Indian cotton. Yarn had to be doubled, polished, singed and spliced instead of knotted, and spooled. The necessary machinery had to be converted or made, and much resource and ingenuity were necessary before thread could be made, But eventually 3,500 lbs. of thread were supplied monthly to the army

Tent factory.

Another result of the war has been the organisation by Messrs. Chettle & Holt, Ltd., of a tent factory and a tape and webbing factory. In the latter factory hand looms only are employed.

General engineering workshops.

Most of the engineering workshops in Madras have been improved in order to manufacture machinery and machinery parts which formerly were imported. Messrs. Massey & Co. have undertaken the manufacture of stocks and dies and screwing tackle generally, and are installing drop stamps in order to manufacture horse shoes on a large scale for the army. At the Madras Engineering Works all the iron bedsteads required for the hospital ship *Madras* were made, and they have also made much sugarcane crushing machinery for the East India Distilleries and Sugar Factories, Ltd. They are now turning out screw-cutting lathes. The Indian Aluminium Company, owing to the impossibility of obtaining aluminium sheets and circles, has turned to other metals and is manufacturi g galvanised iron water bottles, brass cooking sets and gun cotton cases for the army. A new company, the Metal Fittings Manufacturing Company, Limited, has been formed for the manufacture of buckles, shackles, swivels and other metal fittings required by the Ordnance Department. Messrs. George Brunton and Sons of Cochin, who have made for some years past oil engines for draining the submerged paddy lands in Cochin State, have developed their works in many directions. Since the war began, they have supplied to customers all over India more than 30 different types of cylinders for motor cars, motor omnibuses and marine engines, and their success in casting cylinders and other parts of internal combustion engines led them on to building the whole motor. The first motor built proved equal in efficiency to the imported engine it replaced, and as soon as machine tools are available, the firm is prepared to manufacture motors on a large scale. Machinery for brick and tile works has also been built, and satisfactory results are reported to have been obtained from a suction gas plant producer constructed of reinforced concrete instead of the usual rivetted steel plates. Hydraulic pumps for a coir yarn press are also being made. The Madras Electric Supply Corporation and the Madras Electric Tramways, Ltd. were thrown largely on their own resources and were compelled to make for themselves many articles which formerly they procured

from the United Kingdom. Among such articles may be mentioned cement transmission posts, transformer tanks, machine and distributor switch panels, Bastian meter boxes, house service cut-outs, exciter field coils for rotary convertors, car pinions, overhead cars, section insulators and trolley wheels, bushes and heads. Among other new developments may be mentioned the manufacture of pruning knives and other estate tools by Messrs. Aspinwall & Co. of Cochin and the manufacture of looms and loom parts by Messrs. Best & Co., while most of the iron rounds and flats now used in the Presidency are obtained from the rolling mills of Messrs. G udert & Co. at Pondicherry.

Soap and allied industries.

The Madras Presidency is very rich in oil seeds of all kinds, but so far it has been content with a lucrative export trade in the raw material. But there are indications of a change in this respect. The Government Experimental Soap Factory at Calicut on the west coast has been remarkably successful, and it is probable that after the war there will be a considerable development of soap making in Southern India. Messrs. Tata Sons, Ltd., have already floated a company which will establish a large modern copra crushing mill on the west coast and will also, it is believed, take up the allied industries of soap making and the manufacture of edible oils and fats. Messrs. Best & Co. are already refining cocoanut oil at Pondicherry, and the resultant product, under the name of cocoatine, has practically displaced the use of *ghi* in European households in Madras. The shortage not only of imported lubricating oils but also of castor oil is likely to lead in the near future to the manufacture in Travancore of a lubricating mixture from various indigenous vegetable oils and fats.

Miscellaneous industries.

The chemical works of the East India Distilleries and Sugar Factories, Ltd., at Ranipet, have developed in many directions. The output of sulphuric acid and hydrochloric acid has nearly been trebled since the war began, and in addition the company is now manufacturing on a commercial scale nitric acid, epsom salts, green copperas, disinfecting fluids and ink. Experiments are also being made with ink tablets, and the manufacture of stoneware goods for electrical purposes is being investigated. At its sugar factories at Nellikuppam the same company has begun manufacturing golden syrup on a large scale. The paper mill at Punalur in Travancore,

which for 30 years had struggled against adversity, has profited by the opportunity afforded by the war. With the help of the Department of Industries, its machinery has been put in order, and it is now making brown paper from bamboo pulp. The making of pencils has been successfully demonstrated in Madras by the Department of Industries, and the factory has now been sold to a private syndicate. Besides making pencils of all kinds, the factory is turning out copying ink and has experimented with the manufacture of carbon brushes. The manufacture of glue from tannery fleshings has also been taken up by a private firm assisted by the Department of Industries, and promising results have been attained.

Salt manufacture.

Two other developments remain to be noticed. In 1917 owing to tonnage difficulties there was a serious shortage of imported salt in Bengal and owing to a succession of bad years, stocks both in Madras and Bombay were greatly depleted. The Northern India Salt Revenue Department had also sold salt far ahead of their stocks, and a crisis arose. Gambling began in the salt market, and a big rise in prices followed. Everything possible was done in Madras to increase the output of salt, and by opening new areas and increasing the areas under cultivation in existing factories, the total cultivated area was increased from 11,865 acres in March 1916 to 20,000 acres in 1918. In the season which has just closed the outturn of salt was 158 lakhs of maunds or 26 lakhs more than in any previous season. The Salt Department, moreover, is endeavouring to take advantage of the present state of affairs to secure a permanent market for Madras salt in Bengal and to oust the imported foreign article. Bengal wants a pure clean salt, and the Department is endeavouring to introduce an improved process which will result in producing a salt suitable for the Calcutta market. A concession has been granted to a Calcutta firm to work a large factory of nearly 2,000 acres in the Ganjam district for the supply of salt exclusively to Bengal.

Shipbuilding.

The war has also led to a revival of the building of wooden sailing vessels for the coasting trade. These vessels have been built in considerable numbers at Calicut, Cochin, and Alleppey on the west coast and at Cocanada and Masulipatam on the east coast. At Cochin, the firm of Messrs. Brunton & Sons, which for some time past has been making motor launches, is now building a large motor cargo vessel for an Aden firm.

Industrial Expansion in Bombay Presidency.

BY P. J. MEAD, I.C.S.,

Director of Industries, Bombay.

Tendencies of industrial development.

Bombay Presidency is mainly recognised in the industrial world as a centre of textile manufactures, and the big cotton mills in Bombay, Ahmedabad, and Sho'apur, have prospered exceedingly during these months of war, and have also contributed their quota of textiles required for the troops. As an industry, cotton sp'nning and weaving has, from the point of view of the Indian, been mainly a commercial venture, the actual processes being almost entirely carried out under skilled Western direction. The Indian has shown managing ability in varying degrees, but on the whole a considerable measure of prosperity has been achieved and profits have indeed in many years been so easily won that the mi'l industry has absorbed to a very large extent all the business enterprise and capital available. The Swadeshi movement which started in 1906 and passed, through various phases, from a sentimental boycott of all European-made articles to reasonable aspirations towards industrial training and enterprise, first took shape in this Presidency in the Talegaon Glass Works where under Japanese supervision young boys were given an industrial education, and a succession of fairly trained glass blowers have since been distributed all over India. Various other small industrial ventures have been mostly organised and to a large extent manned by Brahmans, who show themselves quick at absorbing new ideas, but somewhat volatile in their rapid changes from one industrial process to another. Thus, in one factory the manufacture of matches was first undertaken; the manager next transferred his allegiance to slate pencils

and finally wound up with experiments in tile making. Considerable sums, generally borrowed from friends at a fairly moderate rate of interest, have been frittered away in these ventures, often undertaken after the briefest and most superficial examination of the sources of raw products required, and with only a slight acquaintance with the processes involved. The factories in many cases have been erected in pleasant climates close to the promoters' homes, without regard to markets or supplies. One prevalent idea underlying many of these ventures is not in itself unsound and may bear useful fruit. There is a good deal of altruism in these Brahman industrial ventures and, in contrast perhaps to the somewhat cynical disregard of their labourers' welfare which strikes the eye in Bombay City, the Wadi or industrial garden city has found favour with several up-country industrialists. The result tends to be a contented labour force and excellent prospects of useful recruitment among the younger generation springing up in these areas. Allegiance to the work in which they have been trained and brought up has not, however, proved sufficiently strong in the case of certain glass works in the Deccan to compete with the temptation of higher wages offered in Bombay City, though probably it has helped considerably.

Setting aside cotton, the exports of manufactured goods are still almost infinitesimal as compared with the raw products, but there have been considerable increases in the exports of castor, groundnut, and sesamum oil, and of castor and groundnut cake, and with improved methods of crushing, refining and probably hydrogenating the final product, there must be great scope for an extension of all these oil-seed industries. Some progress has already been made in respect of the groundnut, and the following brief note by Mr. Mackenzie Wallis shows what has been done in respect of the new flour, which has been christened 'Nutràmine.'

Nutramine.

"Nutramine represents a standard flour prepared from the groundnut (peanut, earth-nut, *mungphali*) after the greater part of the groundnut oil (Arachis oil) has been expressed. This flour is of high nutritive value on account of its protein content, and can be made up into palatable biscuits and bread. The advantage of preparing Nutramine to the oil-mill owner is that not only does he obtain a clean cake selling at a good price, but the quality of his oil is improved without the necessity of a large outlay of capital for additional machinery.

The chief details in the process as worked out in Bombay are as follows :—

(1) The decorticated nuts require to be washed free from dirt, grit, stones, and foreign bodies.

(2) The inner red skin must be removed as completely as possible by breaking the decorticated nut and blowing away the skin by means of a blast of hot air.

(3) The Arachis oil must be expressed in the cold in a hydraulic press or expeller. Using these clean white seeds the resulting oil is quite clear, possesses a pleasant taste, and further has good keeping qualities.

(4) The groundnut cake still contains oil, and this is removed by further expression after the cake has been warmed preferably out of contact with steam.

(5) The resulting cake now contains from 5 to 8 per cent. of oil, and is ground to a fine flour and sieved. Both the fine flour and the uncrushed fragments may be used for biscuit making. The flour constitutes the new preparation known as Nutramine.

The adoption of this flour as a food can be urged both on scientific and economic grounds. The biscuits made from this flour have proved an unqualified success, and the whole industry promises well. At present an attempt is being made to foster this industry in the Bombay Presidency, and investigations are in progress to effect improvements in machinery, and in the purity of finer products. Having established this groundnut oil industry on a sound scientific and commercial basis, attempts will be made to improve other forms of vegetable oils and oilseed cakes."

Casein.

The dairy industry has also been given a considerable fillip by the high prices obtainable for casein. In 1913-14, 3,500 odd cwt. were exported mainly to Germany. In 1914-15, Germany was still our biggest customer, but Italy and the United Kingdom were beginning to be interested. In 1915-16, nearly 4,000 cwt. went to the United Kingdom alone, and America stepped in and took over 6,000 cwt. In 1916-17, nearly 18,000 cwt. went to the United Kingdom, and about 7,000 to the United States, the total value of the exports being about 10½ lakhs of rupees. The original works were set up by a German chemist in Gujarat, who was not very successful with buffalo milk, and is said to have explained to his agents that satisfactory results

could never be obtained with the product of the local buffalo. In this he has been proved wrong, but he displayed at least considerable ingenuity in persuading the local managers of cream separators that casein production was covered by numerous patents, and all the resources of the law would be employed to discomfort any rash person who tried to compete. Since then, casein is made by crude methods in very many Gujarat villages and by the plant left behind by the ingenious Teuton under the supervision of an English firm. The possibilities of casein manufacture are shortly summarised below :—

"Casein is one of the products derived from milk, and associated therefore with the dairy trade. The milk is first treated in a separator, and the cream which separates is used for butter making. The milk is now known as separated milk, and this when treated with acids or rennet yields the so-called curds from which casein is obtained. The curds require to be thoroughly washed to get rid of the milk sugar or lactose, and subsequent purification by solution in an alkali like bicarbonate of soda, reprecipitation by acids, and finally washing and drying of the precipitate. The process of manufacture of casein as at present carried out in the Bombay Presidency is very crude, and the resulting product is of very little value for most industrial purposes. Investigations are in progress to improve this casein. For the production of a good quality casein, special machinery is required, and above all scrupulous cleanliness in all the stages of manufacture. There is reason to believe, however, that the production of Indian casein can be considerably improved, and thus also the quality and quantity of the finished product. That there is scope for a large industry in milk products is evident from an examination of the dairying areas in the Bombay Presidency. Further, if we consider the almost unlimited technical application of casein, we shall see that it is an industry worth encouraging.

Casein enters as the principal constituent of a large variety of paints which retain their colours, and also effectually resist climatic influences. A number of casein paints are already on the market, but the whole question requires a thorough scientific investigation, and the same applies to the present status of industrial casein. Casein is also used as an adhesive and cement, and in this connexion it may be mentioned that a good glue has already been prepared by a firm in Bombay. Plastic masses made from good casein have been extensively employed in Europe as a substitute for horn,

ivory, celluloid, etc., and in this alone the application of casein has unlimited possibilities. Again it has been employed in the textile industry as a dressing and colour fixing medium, and promises to supply a long felt want in the cotton industry of the Bombay Presidency. Finally, casein in a pure form has an extensive field in the domain of foodstuffs, especially for infants and invalids.

The casein at present produced in the Bombay Presidency can be used for the manufacture of an adhesive and for rough paints and distempers, but for other purposes a much purer technical casein is required."

Tanning.

Generally however it is true, as noted above, that Bombay exports mostly raw products, such as sharks' maws and fins, myrabolams, raw hides, raw hemp, oilseeds, and the like. The Munitions Board's control of all tanning and the organisation of Government tanneries at Dharavi have shown however the way to greater possibilities in the future. There is plenty of the one fool-proof tan-stuff, *Cassia auriculata* or the local *tarwad*; and the gothbar fruit (*Zizyphus xylopyra*), which has also been shown to be extremely useful in addition to the local myrabolams, is found in large quantities in many districts. The local *dhor* has plenty of manual dexterity, and, properly trained and under expert supervision, is capable of assisting to turn out high-grade products.

Hydro-electric schemes.

But the real industrial future of Bombay is bound up with our water-power possibilities, and the numerous enterprises of our great industrial leader Jamsetjee Tata and of the firm which he founded. Already from the Khapoli power-house at the foot of the Ghats, power is led into the city across the Thana creek at 100,000 volts and distributed to Bombay mills at the reasonable price of ·55 of an anna per unit. The Andhra Valley scheme is nearing completion, and the projected power available has already been allotted in anticipation. A third line, to complete the supply of electric energy for Bombay City is also under contemplation. The combination of sea-water and cheap electricity is Bombay's greatest asset; and there are large possibilities in the various new electrolytic and high temperature processes, which are making such rapid strides to-day in America. But the above are not the only projects in view. A bigger scheme than any of these contemplates the delivery of power by *ghat*-fed turbines down the Ratnagiri coast, and it is hoped that the extremely

low cost per unit of power which should be possible under this last scheme will render possible various processes such as the making of aluminium from bauxite and possibly the production of calcium carbide and cyanamide.

Glass making.

But while the war has hindered progress with these hydro-electric schemes, it has assisted to promote other industries. The Talegaon Glass Works, as noted above, were started in an altruistic spirit, and with little regard to commercial possibilities, but during the war period they have served India well. Five new glass works have started in Bombay City itself, where there were none before. Some of them owed their inception to the inability of glass dealers to obtain any wares to distribute, unless they made them themselves, and it is probable that some of them have really worked at a loss. They owe their comparative success in any case to the high freights and shipping restrictions operating against Japanese imports, and one of the best managed works in Bombay depends for its success on a Japanese manager and a Japanese assistant as blower. But in spite of their mistakes and uneconomic working in many respects, they have undoubtedly improved the quality of their goods, and there are certainly four or five trained blowers in the Presidency where there was one before the war. There have been difficulties—coal supplies have naturally been irregular, cheap crates are no longer obtainable, and the competition for trained blowers was unsettling for labour. But these difficulties will disappear, and it is possible that the industry may in some form persist even after the war, when there is a fair field for all. At present the Bombay factories have not progressed beyond Japanese direct-fired pot furnaces, and the Japanese crucibles which they use at present are both expensive and bad. White sand for lampware is still obtained from Allahabad at most factories, but there are indications that satisfactory nearer sources of supply can be found; and with an extension of our investigations into pottery possibilities, it should be possible to get fire clay and to make fire bricks, and possibly crucibles, locally. The main difficulty as regards the high price of fuel will always remain in Bombay, but experiments have been made with crude oil which appear to be promising. Improvements in furnace construction are certainly most important, and commercial success must depend in a large measure on considerable economies in firing.

The Eastern Chemical Company.

Unlike Calcutta, there are few British firms in Bombay, which take any lead in industrial enterprise. Local engineering works are of course handicapped by their distance from coal and iron supplies, and the big agency firms have hitherto been mainly importers or export agents. There are signs of change, however, and mention must be made of the Eastern Chemical Company's activities. With the cessation of hostilities, considerable extensions should be possible, and are indeed under contemplation.

During the war its operations have been severely handicapped but considerable progress has been made in several directions. The local climatic conditions have necessitated very considerable adjustments and modifications in the various plant units, but the company now claims to have brought its results into very close approximation to the efficiencies obtained in similar up-to-date plants in Europe. In particular, the relatively high temperature of India adds very considerably to the difficulties of crystallisation, but efforts have been made to evolve means to counteract the climatic disadvantages, with satisfactory results.

A plant for the manufacture of caustic soda has been erected, and the plant is now producing caustic soda of a very high degree of purity in steadily increasing quantities. Owing to the very heavy demand for this product for imperial purposes, however, none of the caustic soda produced has been available for local sales.

A very considerable amount of research work has been done with a view to the utilisation of indigenous raw materials in the manufacture of products formerly unobtainable from other than foreign (to India) sources. The company has also rendered technical assistance to industries not directly or indirectly, if at all, connected with its own operations, with the result that many products which were formerly imported are now manufactured successfully in India.

The company can further claim that its products have been marketed in India at rates comparing very favourably with, and in many cases considerably lower than, the 'controlled' prices of similar products in England.

Saw mills.

Another industry which has been brought into prominence during the war is the saw-mill industry which has expanded considerably in the last few years, and may be expected to assist in the development of local forest

resources in the near future. Mackenzie's Saw Mills in Bombay, one of the largest private mills in India (exclusive of Burma), have been called on by Government since the outbreak of war in several cases where work of urgency or of an intricate character had to be executed. For instance the firm has carried out all the cutting of the various indigenous timbers, with which Government has been experimenting in the hope of obtaining wood suitable for aeroplane construction. A railway siding with large storage sheds and a steam crane was erected by the Indian Munitions Board to facilitate the more rapid handling of aeroplane timbers. The reports on some timbers were favourable and the firm has supplied timbers for aeroplane construction to England and Egypt.

Pottery.

Lastly, it has been shown that there are ample deposits of suitable clays not far from Bombay City, which can certainly be turned to account for making tiles, bricks and the coarser kinds of pottery, and a thorough investigation of pottery possibilities on a small but commercial scale is now under consideration. Small tile factories have been started in the Southern Maratha country round Belgaum, and capital is now being invested, kilns enlarged and remodelled, and the standard of production improved. Transport difficulties, while hampering established industries, have encouraged the temporary establishment of new forms of industrial enterprise, and in some cases local manufactures will probably continue on a permanent basis, though possibly only after financial reconstruction.

Industrial Development in the United Provinces.

By A. H. Silver, C.I.E.,
Late Director of Industries.

Textiles and boots.

The provision of munitions of war has given a strong stimulus to various industries in the United Provinces. The mills and factories of Cawnpore, the industrial capital of the province, have been engaged almost entirely on war work. The Cawnpore Woollen Mills Co., Ltd., which is the largest woollen mill in India has worked continually night and day throughout the war, providing the many items of woollen requirements for army purposes ; Messrs. Cooper Allen & Co., Ltd., proprietors of the Government Army Boot Factory, have provided practically the whole of the boots required by the Army Department, and the Government Harness and Saddlery Factory has naturally been fully employed throughout the whole period in making harness and equipment. All three concerns have greatly extended their output to meet war conditions.

The cotton mills of Cawnpore have been mainly engaged in meeting demands for army clothing and in the provision of large numbers of tents. The manufacture of tents has been carried on at other centres in the United Provinces also, while recently a Government tent factory has been established at Fatehgarh. Indeed the United Provinces may claim to have supplied the bulk of the tents required by Government.

Very large quantities of webbing, tape and newar have been manufactured to the orders of the Munitions Board throughout the province and this has given employment to numbers of village artisans. The manufacture of hand-woven blankets to army specification has also achieved large dimensions, the chief centres being Muzaffarnagar, Najibabad and Bijnor. Muzaffarnagar especially has shown the effects of the prosperity following upon the execution of these large orders.

Other leather and miscellaneous articles.

A comparatively new line of manufacture in the shape of shoulder titles has been established upon a large scale in Aligarh, while orders for clasp knives and cutlery have been placed in Aligarh and Moradabad. The United Provinces have also been the chief centre for the manufacture of *munda* shoes, and large numbers of hand workers in the Cawnpore district have been engaged in providing these, smaller numbers being made in Lucknow and Gorakhpur. These and similar lines of manufacture are concerned directly in the meeting of army requirements, but their manufacture has naturally stimulated production in allied and subsidiary industries. Thus roller skins used in cotton spinning are now being produced in the provinces in large numbers, of a quality claimed to be equal to that of imported roller skins. Leather belting is also being made, and arrangements for the manufacture of pickers (used in all textile mills) and of wash leathers are well advanced.

The demand for tanned leather, not only for manufacture into boots and saddlery but also for export to England to meet War Office demands, has led to a great expansion of the tanning industry in the province and a considerable number of new tan pits have been laid down. An up-to-date factory for the manufacture of cutch (used in dyeing khaki) has been established and is in full working order, and the refining of tallow has achieved success. Large demands for leather buttons have been met and the manufacture of glue is being taken up. The manufacture of rosin and turpentine in the factory controlled by the Forest Department, is progressing, and is described in a separate article.

Glass.

Great progress has been made in the manufacture of glass near Allahabad, whilst a new glass works has been started in the Moradabad district. At the Allahabad glass works, Naini, a large tank furnace has been installed, this being the only one of its kind working in India.

Mention must also be made of the bangle makers at Firozabad. Improved methods of manufacture and the introduction of new styles have helped to render this industry prosperous and there seems to be no reason why it should not be able to hold its own in the future against foreign imports. Austria formerly dominated this trade, but of late Japan has come to the fore as a serious competitor.

Alkali manufacture.

The provision of sodium carbonate to meet the industrial requirements of the provinces was seriously curtailed in the earlier stages of the war and it became necessary to find some special means of meeting requirements, particularly those of the glass makers at Firozabad, who cater for the bangle trade. An experimental factory was consequently started by Government at Cawnpore for the purpose of manufacturing sodium carbonate and caustic soda from *reh*, the efflorescent deposit on *usar* lands. The experiment has proved eminently successful as a war measure, and the plant is now producing nearly 2 tons of sodium carbonate a day at a price which compares favourably with the cost of imported soda of equal purity. Whether such a factory will hold its own under normal conditions has yet to be proved, but the existence of this experimental factory has been of great value during the time of scarcity.

These brief notes are evidences to show that the industries of the United Provinces have made head-way during the war period, and it is hoped that the ground gained during this period will be consolidated as a basis for further development.

Industrial Development during the War in the Punjab.

By C. A. H. Townsend, I.C.S.,
Controller of Munitions, Punjab.

The Punjab is, and must ever remain, in the main an agricultural province—of the wheat that is exported from India to Europe about three-quarters is generally produced in it—and for some years past the demand for labour for agricultural purposes has shown signs of outstripping the supply. When to this demand was added the very large call for men for the army during the war, a call to which the Punjab responded to a far greater extent than any other province, it will be realised that many of the industries of the Province had great difficulty in finding sufficient men to carry on their work during the war. Nevertheless, the Punjab has undoubtedly developed some of its industries very considerably during the last four years, as the following account will show.

Textiles.

The large and well equipped New Egerton Woollen Mills, of Dhariwal in the Gurdaspur District, have since the outbreak of war, been entirely given up to army work, and have turned out very large quantities of woollen goods of all descriptions. Work has been carried on, without ceasing by day and night for long periods. In addition to this, blankets have been made in great numbers for military requirements at many places in the Province, the most important of them being Panipat, in the Karnal district. The work of the best manufacturers has improved steadily all the time. Ludhiana has for some years past made a speciality of many of the less important articles of military equipment, as water bottles, haversacks, puggaries, shoulder-badges and the like, and has turned out many thousands of these during the war. The manufacture of tents has received a considerable impetus, and very large numbers of them have been made, especially at Ferozepore. Puttoo cloth and "lohis" (hill blankets) have also been made in largely increased numbers during the last

four years. Many weavers who had never worked anything else but cotton have learnt how to weave wool also on their looms, to help to satisfy the enormous demands for woollen goods of all kinds, and the experience thus gained cannot but be useful to them in the future.

Wood and metal work.

The carpenters of the Punjab have a well merited reputation, and have justified it during the war. Very large orders for wood work, using the term in its widest sense, for military requirements have been carried out, under the orders of the Deputy Controller of Munitions, at many places in the province. The work of the contractors, many of whom were employed, has, as a rule, steadily improved, and they have learnt, under the instructions of the Deputy Controller, to make many articles they could never have undertaken before the war. Their experiences should stand them in good stead in the future.

The same remarks apply to the blacksmiths of the province. Under the pressure of military demands they have learnt to make, and to make well, many articles they would have deemed far beyond their capacity four years ago. Thus, who, a few years ago, would have thought it possible to make an iron bedstead, complete with springs, in the Punjab? Yet many of these have been made in the last year. In this connection it is interesting to learn that, for some months before the war ceased, the value of the work, principally wood and metal work, carried out for military requirements by the Deputy Controller of Munitions, was about three lakhs of rupees a month.

Cutlery.

Special mention should be made of the manufacture of knives of all kinds, but especially clasp knives, for army requirements, carried out at Wazirabad and Nizamabad, in its immediate neighbourhood. Previous to the war the makers of cutlery used to devote their energies to the manufacture of rather elaborate, but somewhat futile, pocket knives, for sale to passengers at the Wazirabad Railway Station. A better output for their energies was found, and they were turned on to making large clasp knives for army use. Of these they have made, altogether by hand labour, between thirty and forty thousand during the last two years, which have been officially described as "of excellent workmanship, and remarkably cheap." Incidentally I discovered, during one visit I paid to Wazirabad, that one firm at Aligarh in the United Provinces, which had received an order for

similar knives from the Munitions Board, had passed a portion of it on to a Wazirabad manufacturer, for compliance, as a sub-contractor. Efforts will now be made to prevent these people relapsing into the line of manufacture they were in before the war, which, on account of its limited possibilities, may be described as a *cul de sac*, and to find for them a permanent market for the better articles of cutlery they have shown they can make.

Leather work.

The leather work of the Punjab is not good. The raw materials, *i.e.*, hides, are very fair, but they are only too often spoiled by defective flaying, and tanning. To remedy this, if only in part, a short leaflet was produced and widely distributed, which pointed out the more obvious defects of flaying as at present practised in the Punjab, and how they can be easily avoided. Efforts were also made to find a suitable man to be employed by Government to teach the tanners of this Province improved methods, but they failed on account of the great demand for all men with the requisite qualifications, for employment at Cawnpore and elsewhere, in factories engaged entirely on Government work. For the rest, roughly tanned hides were sent in very large quantities from this Province to Cawnpore for use in Government work there, and much leather work was done for the Ordnance Department through the Deputy Controller.

Saltpetre.

The manufacture, by country methods, of saltpetre has increased considerably during the war, to meet the increased demand.

Minor industries.

Of minor industries, dyeing, especially by country methods, has of course assumed considerable importance since the war began. To cope with the problem, Government has started a dyeing school, with an expert dyer in charge in co-operation with the authorities of the Forman Christian College, Lahore, whose chemist, Mr. Carter Speers, takes much interest in industrial chemistry, and will generally supervise the venture. So far it is promising well.

Glass.

The Ambala glass works, which specialise in chimneys, have done very well indeed during the last four years, principally owing to the absence of Austrian competition. They sell their chimneys all through the Punjab and North-West Frontier Province. Japanese competition touches them but little, owing to their distance from the sea. I was indeed told they could sell twice their present output without

difficulty; but unfortunately, their present output appears to be their maximum, on account of shortage of labour. Inspired by the success of the Ambala works, another firm has recently put up glass works in Lahore; it is yet too early to say with what degree of success.

Drugs.

Medicinal herbs have greatly increased in importance since the war. An enterprise has recently been started to exploit the possibilities of the Punjab hills in this direction; and it is proposed to erect a small factory at Doraha, near Ludhiana. A qualified chemist, who has studied the subject, is on the staff. The enterprise, if properly managed, has possibilities.

Jail manufactures.

The industrial activities of the jail department expanded considerably during the war. All the ordinary industries save those which were indispensable to the efficient working of the jails were closed down, and the labour thus made available, nearly all of which is unskilled, was devoted to the manufacture of articles necessary for the war. Of these blankets and tents were the most important, but very many varieties of articles were made. Here again we may hope that the experience gained by many thousands of unskilled labourers in the manufacture of useful articles will prove to be not without its value to them after the war.

The Development of Industries in Burma.

By J. P. Hardiman, I.C.S.,
Contoller of Munitions, Burma.

The outstanding industrial features of Burma are, firstly, the great possibilities of the Province as a supplier of raw material, its resources having as yet been comparatively little drawn upon; secondly, the small extent to which its raw material is worked up in the Province, and thirdly, the handicap to industrial development caused by the shortage and high cost of labour, the want of a cheap fuel, and the paucity of roads and railways. The railway system has yet to be linked up with India on the north and British Malaya on the south. Rice, timber, hides and skins, mineral oil and cotton are the chief exports, rice easily heading the list. The imports are almost entirely of manufactured goods. Among raw materials imported are coal, salt, tobacco, fish and silk, but of these only tobacco and silk are imported for manufacture.

Agriculture.

The Province has fortunately never known more than limited conditions of crop failure. In the rainy southern districts the rice crop is assured, and the same is true of the northern wet belt, as yet little developed. The intermediate section, or dry zone, suffers at frequent intervals from shortage of rainfall and therefore of crop, but the existence of a through railway system, the readiness of the Burman to migrate in search of work, if congenial, and the absence of caste scruples of diet have removed any possibility of famine conditions arising, even in this part of the Province. With the United Provinces and the Punjab, Burma ranks as one of the great Indian reservoirs of food grains, the exportable surplus of rice being nearly 2½ million tons, in value about two-thirds of the total value of the exports. Summing up, the industrial economy of the Province is as yet mainly agricultural, and, to a remarkable degree, dependent upon a single crop.

Timber.

The reserved forests cover 29,000 square miles. This enormous area yielded, in 1915-16, 1·35 cubic feet of timber and fuel per acre, a small fraction of the annual increment of forest growth. Comparatively few species of timber, out of many known to occur, are exploited. Teak is the only timber which is exported on a large scale, being in great demand everywhere, but *pyinkado* (*Xylia dolabriformis*) *padauk* (*Pterocarpus macrocarpus*) and *in* or *eng* (*Dipterocarpus tuberculatus*) have also a considerable sale outside Burma. These are mainly exported in the sawn section, manufactures of wood being practically non-existent. The Burma forests will, when opened out, constitute an immense reservoir of a raw material of which, even before the war, there was a growing world shortage, which has become greatly aggravated during the war, owing to the denudation of woodlands in the belligerent and neutral countries.

Minerals.

The proved mineral areas comprise the oil-bearing region in the dry central districts, and numerous ore-bearing areas in the hilly country on the east. In the north-east extensive deposits of lead, zinc, and silver ore are being actively worked in the Bawdwin mine near Namtu; in the south-east the Tavoy district is the most important of the world's tungsten producing areas. The south-eastern districts also produce tin ore, and the prospects of development of this mineral are favourable. Antimony and copper ore occur, but are not yet worked. The mineral oil products stand almost alone in being exported in the final manufactured form. Rubies and sapphires are mined in the Ruby Mines district, and there is a small pearl industry in Mergui.

Sources of capital invested in industry.

The capital needed to develop the important established industries has been obtained in the main either from British, Indian or Chinese sources, Burmese capital having penetrated but little into organized industrial channels. Rice mills and saw mills, financed and managed by Burmans, are however springing up in some numbers outside the large urban centres. Musulmans from the Bombay Presidency finance a considerable portion of the imports, and some of the export trade, and Chinese from the Straits Settlements also play an important part. The mining industry has depended mainly on British capital. Germans had penetrated into the rice-milling trade before the war, and were stretching out a hand to the tungsten

industry, but Government action has eliminated this factor, and German been replaced by British capital. Banks are conspicuous by their absence. In five towns, Rangoon, Akyab, Mandalay, Moulmein and Tavoy, there are branches of important British joint stock banks. Elsewhere the financing of the Burmese cultivator is carried out largely by Madras money lenders of the *Chetty* caste, but in recent years there has been considerable development, especially in Upper Burma, of co-operative credit banks. There is as yet no industrial bank.

Labour.

The other essential to industrial development, labour, is, like capital, in no small measure supplied from other than Burmese sources. Although the Burman is not trammelled by caste, nor divided by racial or religious cleavage, and the standard of literacy in Burma is much higher than that prevailing in India as a whole, these circumstances, which at first sight would seem to favour the growth of a Burmese industrial community, appear to be more than offset by the dislike of the Burman to working side by side with the Indian, by his preference for an open air life, and his reluctance to submit to the discipline necessarily imposed in an organised industry. With one exception, namely the timber trade, all the large-scale non-agricultural industries in Burma are manned by Indians, not by Burmans. For instance, the Burma Railways Company, the largest land-transport industry, employs 92 per cent. Indians, and only 8 per cent. Burmans out of 16,000 employés. In the Irrawaddy Flotilla Company, the largest water-transport organization, and in the mineral oil companies, the same feature of an organized industry solely or largely manned by Indian immigrants appears. Most of the labour on the mines is Chinese or Indian. The vast extent of, as yet undeveloped, culturable land (36,304 square miles in 1917-18) contributes to attract the Burman to agricultural pursuits, with the result that labour is both scarce and dear, and, until this condition of affairs is mitigated, *e.g.*, through increased immigration, the industrial development of the Province must remain severely handicapped.

Fuel.

A further handicap is the fact that Burma contains, so far as is known, no easily workable and cheap supply of fuel. No coal is extracted at present. Extensive coal-bearing areas exist, but the coal is of indifferent quality and no deposit has yet been proved which is likely to be of more than

local importance, nor has any coking coal yet been discovered. The search for workable deposits continues. Paddy husk and saw dust are used as fuel in the rice and saw mills, and an experiment aimed at securing better combustion of the former is in progress. The fuel is not however suitable for transport, so that Burma is likely to be faced after the war with the continued necessity of importing coal and coke for its industries. A reconnaissance survey of hydro-electric possibilities is to be made during the present cold weather. The existence on the east, of an extensive, high-lying plateau, subject to a heavy rainfall, affords hope of development in this direction, but the factors of the problem cannot yet be estimated.

Development of industries owing to the war.

Owing to its distance from war theatres, the effect of the war in developing industries in Burma was less marked than in some other Indian provinces. Very large quantities of timber were nevertheless extracted for war purposes, being despatched almost entirely in the plain sawn section. A beginning was made with munitions manufactures of the simpler kinds, and there should be no insuperable difficulty in providing many future military requirements of wood at a cheap rate, given a steady sequence of orders.

Shipbuilding.

The shortage of tonnage during the war directed attention to the possibility of building wooden ships in Burma, and several have recently been launched or are under construction, the largest one having a cargo capacity of 1,800 tons. Builders continue to be interested in the industry in spite of the change of circumstances brought about by the cessation of hostilities and the certainty of a decline in freights.

Mining and metallurgy.

The war development of Burma minerals included the active extraction of tungsten ore, various mineral oil products, lead and silver. The ores of tungsten and tin are exported, and the smelting industry is confined at present to lead and silver; the possibility of further developments of smelting therefore calls for enquiry. Zinc sulphide (which occurs with the lead and silver ore) will shortly, it is believed, be shipped to India for the manufacture of India's requirements of sulphuric acid and zinc.

Other industries.

Whilst private prospecting is continually going on, this work and the official geological survey are hampered by the dense forest growth covering many of the

mineral areas. Proof of the existence of the raw material presents in this case difficulties which will in time be overcome, but other raw materials are already proved, and here industrial development can be expedited. Burma hides, up to the present mainly exported in the raw state, are of excellent quality, whilst recent investigation has shown that the dry zone is a congenial soil for the cultivation of *cassia auriculata*, the bark of which shrub is the most suitable material yet discovered for tanning Indian cow hides. In the production of heavy chemicals, the first steps have already been taken. Sulphuric acid (made however from imported raw materials) has been manufactured in Rangoon for some years, whilst caustic soda is now being produced from the saline efflorescence (*reh*) occurring in the dry zone. The secondary industries of paper-pulp and paper manufacture will, it is believed, shortly be embarked upon. The demand for matches is met in part by local manufacture.

Rubber and cotton.

In their geology and configuration, the south-eastern districts resemble somewhat closely the Malay States and the possibility of largely extending rubber cultivation and developing rubber manufactures lies open, should it be found possible to attract the necessary capital and to provide the unskilled and technical labour needed. Cotton is an established crop, the cultivation is extending, and the Province exports considerable quantities of raw cotton, which it re-imports later in the form of twist and woven fabrics. An enquiry into the possibility of establishing a spinning and weaving industry sufficient to deal with the crop might lead to development.

Future development.

No department of Government charged with the special duty of developing industries at present exists. A general industrial survey of the Province remains to be made, and would no doubt suggest many lines for detailed expert surveys. Among industries, agricultural or dependent upon agriculture, to the establishment or extension of which the environment appears suitable, may be mentioned areca nut, cocoanut, wheat, sugar, tobacco, castor and tea. The manufacture of starch and the working up of the products of rice, *e.g.*, rice meal and industrial alcohol, are possibilities which have not yet been examined. The Shan States appear to afford a field for the development of plantations on a large scale and an organized stock-breeding industry.

Among possible lines of development of other than agricultural products may be mentioned lead manufacture, cement, tiles, earthenware and porcelain (the latter from local kaolin deposits), soap, cordage and gunny products, mats and matting, paper-pulp and paper. The prospect of an extended sea-fishing industry obviously calls for examination in a province which has an extensive and varied seaboard, an established inland fishing industry, and a people who consume fish as part of their staple diet. The many possibilities of introduction of new or expansion of existing field crops and the opportunities of industrial development afforded by the forests make it essential that the industrial survey, when made, should be co-ordinated with an agricultural and a forest survey.

The Effect of the War on the Industrial Development of the Central Provinces.

By G. L. Corbett, I.C.S.,
Controller of Munitions, Central Provinces and Berar.

There has undoubtedly in recent years been a general awakening to the theoretical value of industrial development, which is partly due to the war, but still more, I think, to emulation with Japan; to the interest aroused by the Industrial Commission; and to political movements. These industrial aspirations have chiefly affected the educated political classes, who have no practical experience of industrialism.

These aspirations will, no doubt, bear fruit in time; but the immediate practical effect of the war on industrial development has generally, in my opinion, been adverse. The reasons for this are:—

(1) the depletion of staffs both in Government service and in private employment;
(2) the difficulty, if not the impossibility, of recruiting experts from abroad for fresh developments, whether by Government or by private firms;
(3) the difficulty of obtaining machinery and stores from abroad and the shortage and high price of fuel, for the development of power; and
(4) transport difficulties, limiting export of finished goods and the development of new markets.

It has to be remembered that industries in the Central Provinces are still generally in the hot-house stage. Necessity, as in other provinces where industries were already firmly established, has not created a supply of articles essential for the maintenance of existing industries, which were cut off by the war. For the same reason, it has generally been more economical for the Munitions Board to develop the output of munitions in areas which are already

industrialised than to attempt to create new sources of supply in a backward province.

I will now briefly discuss the effect of the war on individual industries.

I.—Big Industries.

Agriculture.

Agriculture is the key industry of this province. At the outbreak of the war the activities of the Agriculture Department had already effected much, and promised early developments of far reaching importance. Owing to the war, the expert staff was depleted for military duty or for agricultural work in Mesopotamia, and it was impossible to get fresh recruits. Not only was further expansion retarded, but it was impossible to maintain the existing cadre at full strength. Again, the war has prevented the import of agricultural implements, oil engines and other machinery; and even indigenous manufacture has been hampered by the want of iron. In particular the development of sugarcane cultivation has been stopped by the impossibility of procuring an adequate supply of cane-crushing mills.

Forests.

The expert forest staff has similarly been depleted; and though it has been possible to carry on existing working plans, it has been impossible to develop the commercial potentialities of important minor forest products, such as lac. The demands of the war have indeed increased the output of grass and sleepers from the forests. But the export of grass has been to meet the exceptionally large military requirements and would not ordinarily be justified as a commercial proposition. The output of sleepers has only been increased as a temporary measure at the expense of sound silviculture, and so far from being advantageous, may actually impair future supplies.

The collection of tanstuffs, however, has undoubtedly derived great impetus from war demands and has been put on a more scientific and commercial basis than formerly. On the other hand, trade in myrabolams, which were chiefly exported to Europe, has suffered.

Mining.

The important coal and manganese industries have generally been dislocated, and expansion has been impaired by the uncertainty of the market, difficulties of transport, shortage of expert mining staff and the difficulty of getting machinery and stores. Some coal mines have made large profits from recent high prices; but this has not been altogether healthy, for it has encouraged people to dabble

in coal who have not the expert knowledge to succeed under normal conditions. On the other hand, some of the more important companies have suffered from forward contracts at low rates which they cannot profitably fulfil at the present cost of labour. The development of the bauxite and iron industries has been similarly retarded.

Cotton mills.

Established mills have made large profits from the high prices which have recently been prevailing, but the increase in output has been hampered by the difficulty of obtaining not only heavy machinery and looms, but also shuttles, bobbins, pickers, etc.

II.—Smaller Industries.

Cement.

Cement works have benefited from munitions demands and are now established as a very profitable industry. But delivery of plant, which was actually ordered in England and would have much increased the output, has been prevented by the war.

Pottery.

Pottery works have benefited from large orders for firebricks, etc., but have been unable to develop finer work owing to the difficulty of obtaining the necessary plant.

Hides and tanning.

The demand for leather for war purposes has awakened many to the possibilities of increasing and improving the output of leather produced from local tanstuffs. But the actual results so far have not been important. On the other hand, the demand for well flayed and cured hides in Bombay and other markets has undoubtedly effected an improvement in the quality of the raw hides exported.

Glass.

The glass factory at Jubbulpore was able to extend its market, but suffered from want of expert supervision. After many efforts a Belgian glass expert was at last engaged, but was drowned in the 'Maloja.'

Oil pressing.

The output of the few oil mills in the Province is almost entirely consumed locally, and the impossibility of obtaining plant has retarded further developments. Some mills which were run by oil engines have shut down owing to the cost and difficulty of obtaining oil. On the other hand, one or two of the larger mills have obtained substantial orders abroad, and have increased their output by installing oil plant which had previously been scrapped.

Paper.

The Agricultural Chemist succeeded in producing paper pulp from cotton stalks, but the machinery which was required to test the experiment on a commercial scale was sunk at sea, and has not been replaced.

III.—Cottage Industries.

Cotton weaving.

The introduction of the fly shuttle by the Textile Expert has been hampered by the difficulty of obtaining the necessary stores from England. Satisfactory shuttles have, however, now been made locally on a small scale. The hand-weavers benefited for a short time from the high price of cotton cloth, but this has been counterbalanced by the very high price of yarn. High prices have also lessened the demand for silk-embroidered cloth, which is a speciality of the Central Provinces' 'Koshta' and does not compete with the mills.

Wool weaving.

The local tweeds which were produced by the Textile Expert, promised to give a sound cottage industry; but this was brought to a standstill by the commandeering for military purposes of all Cawnpore yarn, which was necessary for the warp. It has also been impossible to obtain from England the plant required for the small central factory on which the organised industry would depend.

Brass work.

The introduction of the power hammer and pressing and spinning machinery, which was well in train, has suffered partly from shortage of brass and partly from the difficulty of getting the necessary plant.

Chemical Industries.

By Dr. J. J. Sudborough, *Indian Institute of Science, Bangalore,* and Dr. J. L. Simonsen, *Indian Munitions Board.*

I.—Introduction.

In a modern state the development of chemical industries on a scale that renders them an important factor in the economic life of the state—as they are in England, Germany and America—necessitates the provision of certain essentials at sufficiently low rates.

Essentials for the development of chemical industries.

(1) Fundamental heavy chemicals.

First of these are the fundamental heavy chemicals, the most important of which are sulphuric and hydrochloric acids, lime, sodium carbonate, caustic soda and ammonia or ammonium salts together with common salt and, if a coal tar industry is included, nitric acid. These fundamental chemicals are essential as they are used so largely in the production of other chemicals from indigenous sources. For example, sulphuric acid is required in the manufacture of hydrochloric and nitric acids, in the production of sodium carbonate in the Leblanc process, in the manufacture of alum and other metallic sulphates and in the manufacture of superphosphates. These common or fundamental chemicals are also largely used in the refining of various natural products or of materials derived from natural products; thus large quantities of sulphuric acid and alkali are required for refining fixed oils and mineral oils.

(2) Fuel for power, heating purposes and metallurgical operations.

The general industrial development of England—a development including that of the heavy chemical industries—is usually attributed to the fairly wide distribution of coal fields in England, to the good quality of the coal and to the fact that in the early nineteenth century the coal could be worked at a

comparatively low depth. The coal fields in India are not widely distributed. The chief centre is Bengal and Bihar, and of the 18 million tons of coal raised in India in 1917 sixteen and a half million tons came from this field. Coal of low grade is found in Assam, Hyderabad and in the Punjab and recently coal has been discovered in the Northern Shan States of Burma.

Coal as fuel is comparatively cheap in Bengal and hence this would appear to be the most suitable centre for certain chemical industries requiring cheap coal or coke.

It is clear that it would be impossible to hope to work an industry in South India successfully from a financial standpoint if large quantities of coal were an essential. For many purposes wood can be used as a substitute for coal and although as a source of heat or power its efficiency is much less, *e.g.*, the comparative heating values for equal weights can be usually taken as about 1·2 in many parts of South India the lower cost of the wood compensates for this low calorific value. For certain purposes, charcoal can be used when a fuel of high calorific power is required, and the possibility of producing, at a comparatively low cost, large quantities of wood charcoal from the waste woods of the forests needs careful consideration. The scheme of the Mysore Government for making charcoal iron in the Shimoga district is based upon the cheap production of charcoal from the timber in the adjacent forests.

In the modern industrial world cheap electricity is an essential for certain chemical operations. The electric energy may be used (*a*) as a source of power for running machinery, (*b*) for producing high temperatures as in operations where the electric furnace is used (*c.f.*, calcium carbide p. 229) and in electro-metallurgy, or (*c*) for actually bringing about chemical changes, as in the electrolytic processes for producing alkali, chlorine, aluminium or magnesium. Such cheap electricity is generated with the aid of either fuel or water power. In many parts, electric current at 0·5 anna per unit (Rs. 205 per H. P. year) can compete with steam. On the other hand, electric current required for electro-metallurgic or for electrolytic processes must be much cheaper, as the products manufactured by the aid of such current will have to compete with similar materials produced in North America and Scandinavia where current can be generated from water power at from 0·1 anna to 0·05 anna per unit.

In this connection it may be pointed out that India suffers from a considerable disadvantage when compared with America or European countries where big hydro-electric schemes have been developed. Owing to Indian climatic conditions, in most centres where hydro-electric power stations could be erected, it is found that there is an excess of water during certain months and a great shortage during the hot season. This means that either enormous dams must be constructed in order to retain during the monsoons the excess water which can subsequently be used in the dry season, or the electro-chemical and electro-metallurgical factories must be shut down during periods of drought. The first method means big capital expenditure and hence an increase in the cost of current, and the second necessitates that money locked up in valuable plant and machinery will be unremunerative during several months of the year (see page 154).

(3) Chemical plant and machinery.

Most chemical industries require special plant in addition to the ordinary requirements for power or steam. Such plant may be of the comparatively simple nature of mixers, stills and evaporating pans or may take the form of the more complex autoclaves, filter presses, centrifugals and multiple effect evaporators. Before the war all such plant and machinery was imported, but it is clear that the growth of big chemical industries would be facilitated by the production of much of the simpler plant in India.

Boilers, stills, evaporating pans and even autoclaves could be made in the country. A start in this direction has been made, for example, all the stills required for the Mysore Government Sandalwood Oil Factories were made in Madras.

The best lines of development.

In any attempts to foster the development of chemical industries in India attention should be directed, in the first instance, to industries which make use of the Indian grown raw materials now exported to other countries, where they are worked up into various finished products. Included in these exports are (1) the raw materials from which important fixed oils and feeding cakes are manufactured (p. 77), (2) the raw materials from which valuable essential oils (p. 90) and medicinal drugs are prepared and (3) various mineral products such as chrome, manganese and zinc ores, wolfram and monazite sands, all of which are exported to Europe and are there worked up into important metallur-

gical or other technical products. The production in India of all the common salt consumed in the country, both high grade salt for edible purposes and lower grades for industrial purposes (p. 70) seems also well within the range of possibility.

The development of certain specific industries may be relatively simple. If India is practically the only producer of the raw material in question, the working up of the raw material and the export of the finished product may be comparatively easy, as competition from foreign countries is eliminated. In most cases, however, such as oil seeds, minerals, etc. India is not the only producer and during the early stages of developing the industry keen competition with foreign countries must be expected. In fact it is possible that certain countries or foreign firms will be prepared to flood the Indian market with a product at less than cost price in order to destroy a struggling industry during the first years of its inception.

The whole problem is complicated by tariff questions. The desirability of introducing export duties on raw materials but of allowing free export of the corresponding manufactured products, *e.g.*, export duties on sandal wood, ajwan seed, copra, crude saltpetre, monazite sands but free exports of sandalwood oil, thymol, cocoanut oil, pure potassium nitrate, and thorium compounds has to be considered. On the other hand, foreign countries will frequently allow Indian raw materials such as oil seeds or minerals to be imported free of duty but levy a relatively high tariff when attempts are made to import the finished products derived from these raw materials.

II.—Mineral Acids.

Sulphuric acid.

Sulphuric acid may be regarded as the "key industry" for all chemical industries and it has been claimed that the wealth of a country can be gauged by its production of sulphuric acid. As the acid is extremely cheap and also excessively corrosive, it follows that, as a rule, freight charges will be relatively heavy and hence it is usually necessary to manufacture in certain centres where large quantities are required.

Some idea of the quantities produced in Europe and America may be gathered from the fact that the United Kingdom and France each manufacture about one million tons a year, while Germany produced about 1,650,000 tons in 1912 and the United

States of America about 2,876,000 tons in 1912 and 3,765,000 tons in 1914, the latter figures including about one million tons from zinc works. Since 1914 these figures must have been increased to an enormous extent, as very large quantities were required for producing phenol, trinitrotoluol, nitrocelluloses and other explosives. The output of the United States of America for 1917 is given as 7 million tons. In France, Italy and the United States of America the great bulk (about 70 per cent.) of the acid produced prior to 1914 was used in the manufacture of superphosphates for fertilizing purposes.

The quantity imported into India in 1912-13 and 1913-14 varied from 2,000 to 3,000 tons a year and it is estimated that about 18,000 tons are actually manufactured in the country, so that in India this 'key' industry is quite in its infancy.

The great bulk of the acid made in Europe is produced by burning iron pyrites and oxidising the gaseous sulphur dioxide by means of nitrous fumes, air and moisture in leaden chambers to chamber acid, which is subsequently concentrated. Such acid invariably contains arsenic as an impurity and has to be de-arsenicated before it can be used for certain specific purposes where arsenic would be injurious. The London price of ordinary 50°B acid was 32½ shillings per ton in 1913 but rose to 83 shillings in 1918.

As large deposits of iron pyrites have not been met with in India, practically all the sulphuric acid is made by burning sulphur imported from Sicily or Japan. This yields a good quality acid, free from arsenic, but is much more expensive. In 1917 the price of pyrites in the United States was practically one fourth that of sulphur. The price of imported sulphur in India in 1913 was about £5-6 per ton and as 1 ton of sulphur yields about 3-4 tons of sulphuric acid, it is clear that, even if the factory costs are reduced to their minimum, the selling price of Indian-made sulphuric acid in Calcutta or Madras must be much higher than the ordinary pre-war price in London.

The need for careful chemical control and supervision in a modern sulphuric acid factory is illustrated in two recent papers in the Journal of the Society of Chemical Industry (1917. *36. 196.* 491). Without such control the plant is inefficient, the yield of acid low and hence the price relatively high. It is probable that many of the sulphuric acid plants in India, most of which are comparatively small, are run somewhat inefficiently.

The future of the industry in India is promising, as it has been decided to work up at Singhbhum the Burmese zinc concentrates for the production of spelter (zinc). These concentrates consist largely of zinc sulphide, and when roasted produce sulphur dioxide, which can be used for the production of sulphuric acid in the ordinary lead chamber. As the sulphur dioxide is a by-product, its cost should be much less than sulphur dioxide produced by burning imported sulphur, and hence the cost of producing sulphuric acid in India should correspond more nearly with that of American or European acid.

The following tables give the imports of sulphur and sulphuric acid into India during the past six years. It is clear from these tables that the quantity of imported acid has diminished, and the increased imports of sulphur are mainly due to the larger amount of acid manufactured in India.

TABLE 1.—*Imports of sulphuric acid.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	1,939	*24,732*
1913-14	3,196	*36,664*
1914-15	1,231	*21,961*
1915-16	257	*5,603*
1916-17	82	*2,861*
1917-18	21	*978*

TABLE 2.—*Imports of Sulphur.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	5,749	*35,810*
1913-14	6,327	*39,894*
1914-15	6,101	*41,538*
1915-16	8,477	*58,909*
1916-17	8,966	*89,000*
1917-18	9,785	*111,790*

Large quantities of sulphuric acid are used in the manufacture of super-phosphates, hydrochloric acid, nitric acid, the metallic sulphates, such as epsom salts, alum, sulphate of iron, zinc, etc., in the refining of oils and in pickling iron. In Europe and America, large quantities are also used in the explosives and dye industries.

In the dye industry, a product known as fuming sulphuric acid is required and this is now manufactured by what is termed the contact process. Ordinary concentrated sulphuric acid can also be made by the same process and it is possible that this method might be used in India. The method consists in passing pure sulphur dioxide and oxygen at a suitable temperature over a catalyst such as platinum, ferric oxide (pyrites ashes) or alloys of tungsten and collecting the sulphuric anhydride thus formed in sulphuric acid of suitable strength. The cost would be comparatively high, as great care is required in the supervision and the plant could only be run by a chemist accustomed to the process. (For modern methods of sulphuric acid manufacture see Moss, Journal of Society of Chemical Industry, 1918. *37*. 68 T.)

Nitric acid.

Nitric acid is now made in India in quantity sufficient to meet the demand and we are given to understand that with the plant at present available any reasonable increase could be met although, of course, should the manufacture of dyes or explosives be undertaken considerable extensions would be required. The imports are small.

TABLE 3.—*Imports of nitric acid.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	257	*9,750*
1913-14	243	*8,869*
1914-15	164	*7,454*
*1915-16	46	*4,437*
1916-17	142	*14,396*
1917-18	3	*206*

*Figures for Bengal not available.

The acid is manufactured by heating sodium nitrate (Chili saltpetre) with sulphuric acid. The imported nitrate is preferred to Indian saltpetre (potassium nitrate), since it is cheaper and is less liable to contain chlorides, which must not be present if a good quality acid is required. The purification of the potassium nitrate presents no great difficulties and it is possible that with improved methods a pure saltpetre could be produced as cheaply as the material containing several per cent. of chlorides now put on the market. A further advantage, which would result by the substitution of potassium for sodium nitrate, is that the by-product from the manufacture, potassium hydrogen sulphate, is of much greater value than the corresponding sodium salt, as it can be used as a potash fertiliser after neutralisation with lime. A by-product formed when Chili saltpetre is used is acid sodium sulphate. The quantity of this product turned out in Europe and America is considerable and various methods have been proposed for utilising it (*cf.* Journal Society of Chemical Industry, 1919. *36.* 1216 A, also Grossman *ibid* 1035, 1761; 1918. *37.* 103 T).

The question of replacing or supplementing the present method of manufacture by one of the processes now in use in other countries for utilising atmospheric nitrogen is one which requires careful consideration, if the manufacture in India of explosives and dyes is contemplated.

Hydrochloric acid.

The main source of this acid in Europe is as a by-product in the manufacture of soda by the Leblanc process and it is therefore placed on the market at a very low rate* It can be readily prepared by heating common salt with sulphuric acid and its price is dependent therefore mainly on that of sulphuric acid. As sodium carbonate is not manufactured in India by the Leblanc process, the sodium sulphate formed in this reaction is of little value and this fact also tends to increase the price of the acid. The price of the commercial concentrated acid in 1914 was Rs. 300 per ton in Madras. With a supply of cheap sulphuric acid it will doubtless be possible to put hydrochloric acid on the Indian market at a price which will render its use in other industries more feasible.

The Indian output at present is approximately 600 tons per annum, whilst comparatively little is imported.

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*£1-12 per ton [quoted from Molarini, Inorganic Chemistry, p. 159.]

TABLE 4.—*Imports of hydrochloric acid.*

Year.	Quantity.	Value.
	Tons.	£
*1913-14	14	442
*1914-15	163	4,740
*1915-16	100	6,153
†1916-17	120	7,844
1917-18	42	3,302

*Figures for Bombay and Sind not available.
†Figures for Bengal not available.

This acid is mainly used in the manufacture of chlorides, more especially zinc chloride, the pickling of iron, the purification of ores, and in the colour and pottery industries.

III.—*Alkalies and Common Salt.*

Ammonia.

Until the recent methods for the utilisation of atmospheric nitrogen for the manufacture of ammonia and nitric acid were developed, the sole commercial source of ammonia was the ammoniacal liquor recovered in gas works and coke ovens. The ammonia so obtained is formed by the decomposition of the nitrogenous matter present in the coal, passes over with the issuing gases, and is removed by the use of suitable scrubbers. The crude ammoniacal liquor is usually boiled with lime and the ammonia passed into sulphuric acid, when crystallised ammonium sulphate is formed. This is used as a fertiliser or for the manufacture of other ammonium salts or of ammonia itself.

Ammonia gas is largely used in refrigerating plants and has not, owing to lack of plant, been made in India, whilst the salts such as ammonium chloride and carbonate find various technical applications. As is pointed out on page 107 the present Indian output of ammonium sulphate is in excess of requirements. In the following tables (tables 5 and 6) the imports of ammonia and its salts into India are shown.

TABLE 5.—*Imports of aqueous ammonia and ammonia gas*

Year.	Aqueous ammonia.		Ammonia ga[s]
	Quantity.	Value.	Quantity
	Tons.	£	Tons.
1913-14	*¼	*54*	*3
1914-15	†3½	*314*	†11
1915-16	†4	*380*	‡18
1916-17	4	*471*	§45
1917-18	8	*928*	§16

*For Burma only.
†Except Madras and Bengal.
‡Except Madras, Bengal and Sind.
§Except Bengal.

TABLE 6.—*Imports of ammonium salts.*

Year.	Ammonium carbonate.		Ammonium chloride.		Ammonium
	Quantity.	Value.	Quantity.	Value.	Quantity.
	Tons.	£	Tons.	£	Tons.
1913-14 . .	*43	*2,160*	*53	*2,064*	¶204
1914-15 . .	†50	*2,396*	‖326	*12,509*	‡159
1915-16 . .	†30	*2,062*	†370	*16,398*	‡150
1916-17 . .	†37	*3,725*	†314	*16,708*	§6
1917-18 . .	†69	*6,691*	†377	*24,907*	*Nil*

*Except Bombay, Sind and Bengal.
†Except Bengal.
‡Except Burma and Sind.
§Bengal and Burma only.
‖Except Bengal and Madras.
¶Except Bombay and Sind.

Sodium carbonate and caustic soda.

Second only to sulphuric acid in importance for the development of chemical industries are the alkalies, sodium carbonate and caustic soda, since little expansion of other industries can take place, unless these chemicals are available in large quantities at low rates. The following table indicates the magnitude of the imports into India.

TABLE 7.—*Imports of sodium carbonate and caustic soda.*

Year.	Sodium carbonate.		Caustic soda.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1912-13	13,856	*74,574*	4,942	*53,534*
1913-14	21,157	*106,172*	4,910	*58,379*
1914-15	22,628	*116,423*	5,905	*70,311*
1915-16	27,639	*157,117*	4,395	*64,845*
1916-17	18,376	*129,740*	2,855	*79,128*
1917-18	35,014	*288,194*	5,855	*222,861*

Crude sodium carbonate, contaminated with varying amounts of common salt and sodium sulphate, is found as an efflorescence in certain districts during the hot weather. This alkaline earth or *reh* is collected and used by *dhobies* for washing purposes. The increase in the prices of sodium carbonate owing to the war led to further investigation of these alkaline earths, and fairly pure sodium carbonate was extracted in both the United Provinces and Mysore, the method adopted being somewhat similar to that used for extracting saltpetre from the soil in Behar and the Punjab. It is certain that such methods will not prove profitable when the price of the chemical falls.

In Sind, and especially in Khairpur State, larger quantities of sodium carbonate—also in most cases somewhat crude and mixed with chloride and sulphate—have been met with as deposits in the basins of certain lakes. In 1915-16, about 350 tons were produced in the Nawababhat District, and about 3,600 tons of this crude product were available in Khairpur State. It is used mainly for

washing purposes, for making soap and in cooking. These deposits ar being examined in order to see if refining on a comparatively larg scale would be profitable, but in any case it is very doubtful if th whole requirements of the country could be supplied from sucl sources.

The possibility of the manufacture of both these chemical in India in sufficient quantities and at rates such that they coul compete with the imported articles needs careful consideration This manufacture may be regarded as a key industry, as sodiun carbonate and caustic soda are essential for many industries, o which amongst the chief may be mentioned soap, glass, dye works coal-tar and oil refining.

The oldest process in use for the manufacture of sodium carbo nate is that known as the Leblanc process. This process is stil in use in Great Britain, but it has been largely supplanted in German and elsewhere by more modern methods of manufacture. The Leblanc process consists in melting together salt cake (sodiur sulphate), coal or coke and limestone, when the sulphate undergoes reduction to sodium sulphide, which then reacts with the limestone, yielding sodium carbonate and calcium sulphide. It is doubtful if the process could be introduced with success into India, as it demands a large supply of cheap sulphuric acid (for the manufacture of the sodium sulphate), and the disposal of the excess of hydro-chloric acid produced in this stage of the process would probably present difficulties. For the manufacture of the carbonate two methods would appear more likely to meet with success, either the ammonia soda process, which requires as raw materials, ammonia, salt and carbon dioxide (obtainable from limestone) and yields as a by-product calcium chloride, for which there would appear to be a large demand in India; or electrolytic processes, in which a mixed solution of caustic soda and salt are produced, the caustic soda being subsequently converted into sodium carbonate by treatment with carbon dioxide, and then separated from the common salt. The ammonia soda process has been worked in Japan during the war and large quantities of sodium carbonate manufactured, but it is thought that the costs are too heavy to enable the product to compete with imported carbonate in normal times.

The manufacture of caustic soda is dependent to some extent on that of the carbonate, since it can be readily obtained from the latter, by digesting its aqueous solution with lime, filtering the

product and evaporating the clear liquid. During the last few years, this method has been adopted in several districts in India, owing to the difficulty of obtaining the imported article.

The bulk of the caustic soda now manufactured in America and Europe is produced electrolytically from aqueous solutions of common salt. When mercury is used as the cathode, an aqueous solution free from common salt is obtained, but with other types of cells, *e.g.*, the bell and diaphragm cells, the liquid obtained contains both caustic soda and common salt which can be separated during the process of evaporation. Two important by-products are obtained when the electrolytic method is used, *viz.*, hydrogen and chlorine. For the establishment of this industry in India cheap current (p. 59) is an essential and the cost of the main product, caustic soda, could only be reduced to a figure comparable with the selling price of the imported article by making use of the by-products. The hydrogen could find a market for the refining of oils by hydrogenation, whilst the chlorine could be used for the manufacture of bleaching powder, chloroform and halogenated solvents, such as chlorinated ethanes, used in solvent extraction plants.

Probably, the most dangerous competitor which Indian alkali would have to meet is the sodium carbonate from Lake Magadi in East Africa. This is available in practically unlimited quantities and the sea carriage to India is short. If the manufacture of sodium carbonate and caustic soda is to be looked upon as a "key industry" then it may prove desirable to protect it, until such a time as the industry is thoroughly established.

Common salt.

Common salt, sodium chloride, is a substance of fundamental importance, both for use in chemical industries and for human consumption. In 1914, one and a half million tons were produced in India. About 60 per cent. of this was produced from sea water by solar evaporation in the Bombay and Madras Presidencies, about 16 per cent. from the Sambhar lake in Rajputana, 11 per cent. from the rock salt beds in the Punjab, one per cent. from the salt deposits of Sind, which are stated to be very extensive, and smaller quantities from the sub-soil water at Kharagoda in Gujarat, and also as a by-product in saltpetre refineries. The majority of saltpetre refiners, however, throw away the crude salt they recover, as they consider the purification would not repay the duty which is levied.

Although the quantities manufactured in India have altered only slightly within the period 1914-16, the value has increased some 45 per cent. as shown in the following tables :—

TABLE 8.—*Salt Production in India.*

Year.	Quantity	Value.
	Tons.	£
1914	1,348,225	*483,289*
1915	1,745,521	*660,254*
1916	1,488,649	*728,356*

TABLE 9.—*Production of rock salt in India.*

Year.	Quantity.	Value.
	Tons.	£
1914	156,550	*24,248*
1915	179,792	*32,782*
1916	184,904	*34,706*

The salt manufactured in India from sea water is usually not a high-grade article. A good deal of it is contaminated with earthy matter, and has a yellow or brownish colour and leaves a residue when dissolved in water. As a rule, it also contains appreciable amounts of magnesium chloride and thus tends to become damp in a moist climate. Undoubtedly the quality and quantity of salt manufacture could be improved. Some of the points which require attention in order to obtain such results are :—

(1) The manufacturer sells by measure and the Government duty is levied by weight. Hence the merchants prefer a light salt, and any improved methods of production which might tend to give a heavy salt meet with opposition.

(2) In most factories the salt crystals are not washed to free them from the mother liquor and hence there is a relatively high percentage of magnesium chloride in the salt.

(3) The yield of salt per acre of evaporating pans varies enormously, *e.g.*, in the Madras Presidency from 200 to 6,400 maunds per acre per year. This is partly due to climatic conditions, as the quantity of salt which can be produced will vary with the number of dry sunny days. It is probable, however, that in some factories low yields may be due to loss of concentrated brine by leakage in the crystallising pans.

(4) The presence in each important district of a Revenue Officer with a training in chemistry would probably result in improvements in the manufacture.

The mother liquor, run off from the common salt, which separates in the crystallisers, is termed bitterns and is very rich in magnesium salts and also contains smaller quantities of potassium and bromine compounds, and could be used as a source of manufacture of compounds of these elements (*cf.* p. 307).

Although very large quantities of salt are made in India, the output is not sufficient to meet the total demands of the country as shown in the following table:—

TABLE 10.—*Imports of salt into India.*

Year.	Quantity.	Value.
	Tons.	£
1914-15	465,694	*493,569*
1915-16	548,940	*1,264,054*
1916-17	445,426	*1,276,375*
1917-18	336,985	*1,467,193*

Nearly the whole of this imported salt is of high-grade quality, and is used in Bengal where a fine-grained white salt is appreciated. Of the imports about one half come from the British Empire, mainly from Liverpool and Aden. The possibility of improving the quality of the bulk of salt manufactured in the Madras Presidency, of

producing a high-grade table salt suitable for the Calcutta market and of increasing the total output of salt, so that India should be independent of the imported article, has recently received some attention. The production of a high-class fine-grained salt can be accomplished by re-crystallising the ordinary Indian salt and boiling the solution rapidly as the salt separates, or by taking greater care in the original manufacture and then grinding the product in a suitable type of plant.

IV.—Coal Tar.

Coal tar derivatives.

The importance of coal tar, in any complete scheme of chemical industries, is evident when it is pointed out that this raw material is the source from which the following types of organic chemicals are manufactured :—

(*a*) *High explosives for filling shells, as contrasted with propellant explosives.*—Tri-nitro-toluene has been used by Germany since 1902 and is the well known trotyl or T. N. T. of the British Service. It is also a constituent of explosives used in Austria and Belgium. Picric acid (trinitro-phenol) was used for years by the French Government under the name of melinite, and by the British Government under the name of lyddite, and was also the chief constituent of explosives used in the United States, Italy and Japan. Dinitro-naphthalene mixed with ammonium nitrate is used as a blasting explosive, and also by the French Government for filling high explosive shell under the name of schneiderite.

(*b*) *Aniline dyes or synthetic dyes.*—Alizarine, which in Europe has completely replaced the natural dye obtained from the madder root, and synthetic indigo are manufactured from products made from coal tar. All the members of the groups of dyes known as triphenylmethane dyes, azo dyes, indanthrene dyes, and sulphur dyes, are manufactured from coal tar products.

(*c*) *Synthetic drugs, as contrasted with the natural drugs, derived from plants.*—The well known antipyretics, antipyrine or phenazone, antifebrine or acetanilide, phenacetine or ethyl ether of p-acetaminophenol; the antineuralgics, salicylic acid and its salts and acetyl-salicylic acid or

aspirin, known also in England under the names of empirin and regepyrin; local anaesthetics, such as anaesthesin or ethyl p-aminobenzoate, novocaine and beta-eucaine; modern drugs used for protozoal diseases, *e.g.*, the azo dye, trypan blue, atoxyl for sleeping sickness, salvarsan (or kharsivan) for syphilis and the recent dyes, introduced as general antiseptics, *e.g.*, the yellow dye acriflavine, are all manufactured from coal tar products.

(*d*) *Photographic chemicals.*—All the well known developers, pyrogallol (trihdroxybenzene), hydroquinone (p-dihydroxybenzene), rodinal (p-aminophenol hydrochloride), and the isomeric compounds, metol and ortol, are benzene derivatives and eikonogen is a naphthalene derivative. All the sensitisers used for producing orthochromatic and panchromatic photographic plates are coal tar dyes.

(*e*) *Synthetic flavouring and odoriferous materials.*— The following well known substances are all derived from coal tar products:—artificial musk, coumarin (the odour of new mown hay), oil of wintergreen and salicylaldehyde (the odour of meadow sweet).

The common sugar substitute, saccharin, which is 500 times sweeter than sugar is also derived from coal tar.

TABLE 11.—*Imports of dyes and drugs.*

Year.	Dyes.		Drugs.
	Quantity	Value.	Value.
	Tons.	£	£
1912-13	8,173	*765,404*	*275,590*
1913-14	7,252	*706,731*	*301,738*
1914-15	3,554	*317,500*	*267,691*
1915-16	320	*113,903*	*330,220*
1916-17	480	*436,118*	*414,643*
1917-18	954	*652,050*	*320,438*

TABLE 12.—*Imports of carbolic acid and naphthalene.*

Year.	Carbolic acid.		Naphthalene.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1913-14	40	*1,288*	*16	*246*
1914-15	44	*1,099*	†33	*563*
1915-16	43	*1,899*	47	*1,653*
1916-17	46	*2,492*	2	*174*
1917-18	32	*2,219*	136	*11,571*

*Burma and Madras only.
†Except Bengal.

The two sources of coal tar are gas works and coke ovens :—

(*a*) In gas works, coal is distilled at high temperatures in closed retorts, for the manufacture of coal gas, for heating and illuminating purposes. The amount of tar available in India is very small as only two fair sized gas works are in operation, *viz.*, at Bombay and Calcutta.

(*b*) In coke ovens, coal is carbonised with the object of producing coke required in enormous quantities in the metallurgical industry. In the old fashioned beehive ovens, the by-products such as ammonia and tar were not recovered. Germany led the way in the introduction of by-product recovery ovens, and these are now replacing the older beehive ovens. They are more expensive to erect, but the extra initial cost is more than compensated by the values of the ammonia and tar recovered. In India, such by-product ovens have been installed and coking in beehive ovens is gradually ceasing. The tar is not however distilled on any considerable scale, nor is any attempt made to recover the toluene, etc., from the oven gases.

Constituents of coal tar.

Although coal tar contains upwards of 200 chemical compounds, many of these are present in small quantities and are not isolated. The five important constituents are benzene (or benzol), toluene (or toluol), phenol

(or carbolic acid), naphthalene and anthracene. These are isolated by processes of distillation and subsequent refining, and in the crude or refined form are used for the manufacture of the dyes, drugs or chemicals already mentioned. Another product of commercial importance is the creosote oil so largely used in the wood pickling industry ; each ton of tar yields about 17 gallons of creosote oils.

The importance of coal tar in any development of the "fine chemical" industries is obvious, and the possibility of any such development in India depends on the amounts of coal tar available in the country, and also on the richness of Indian tars in the important constituents from which the valuable chemicals already enumerated are manufactured.

At the present time, the quantity of coke being made in India is approximately 520,000 tons per annum, yielding about 8,000 tons of tar*. Assuming that the content of benzene, toluene and phenol is the same as in European tar, this would yield approximately per annum twenty-two thousand gallons of crude benzol (benzene and toluene) and six thousand five hundred gallons of carbolic acid.

The introduction of scrubbing plant for recovering benzene and toluene from the coke oven gases might yield, in addition, two million gallons of crude benzol. An examination of coal tar from Indian coals has further proved them to be relatively poor in phenols, so that the figures given above are probably too high.

A comparison of some of these figures with the corresponding figures for Great Britain and America are of interest. In Great Britain, in 1916, fourteen and a half million tons of coal were coked in by-product coking plants, and in America, in 1915, 20 million tons were coked in by-product ovens and 42 millions in beehive ovens. The output of benzol (crude benzene) in the United States of America in 1914 is stated to have been four and a half million gallons and this had risen by 1917 to forty million gallons.

It is quite clear that the amounts of tar available in India under present conditions are quite insufficient to start a large coal tar industry. It, therefore, appears that the only method by which the coal tar industry could be developed in India, would be to coke at the pit head all suitable Indian coal, and to send the tar and also the oils recovered from the oven gases to a central refinery. Such a

* All this tar is not manufactured in by-product recovery plants. If this were done approximately 16,000 tons of tar would become available, since 1000 tons of Indian coal are said to yield about 21·4 tons of tar.

scheme would have the advantage of diminishing the smoke nuisance caused by the burning of coal; but at present, this nuisance is not so prominent in India as in Western countries. Large quantities of combustible gas and of ammonia would also be produced. The former could probably be used for the generation of electric power on a large scale, and the ammonia would be converted into sulphate. In most countries, the ammonium sulphate thus obtained would be used as a fertiliser, but as India already exports 2,000 out of her 3,000 tons of ammonium sulphate now manufactured, the question of the disposal of much larger quantities of sulphate needs careful consideration.

V.—Vegetable Oils.

Uses of vegetable oils.

The Empire's resources in oil seeds are probably next in importance to its coal and mineral resources. This is largely due to the increasing importance of the products obtained from such seeds. The world's demands for all types of soaps have increased enormously within recent years; and vegetable oils and tallow are the raw materials from which such soaps are manufactured. The higher grades of oil are of general use for culinary purposes. At one time olive oil was the staple domestic oil in Europe, but at the present time groundnut, cotton seed and gingelly oils are also used. The increased demands for smokeless powders and explosives of the dynamite and cordite types have necessitated the production of glycerine on a larger scale, and the greater part of this has been obtained from soap and candle factories.

The introduction into America and Europe of butter substitutes has opened up a new field for the use of vegetable oils, which has been increased to an enormous extent by the process of hardening oils by hydrogenation. By this process, the consistency of a liquid vegetable oil such as groundnut can be altered to that of a pasty solid, analogous to butter, or to that of a hard solid suitable for candle making. Vegetable oils are also used for lubricating purposes, as illuminants and also in medicine.

The British Empire is fortunate in having within its confines two countries, India and East and West Africa, the vegetable oil resources of which are of vast proportions. The chief oil seeds produced in India are linseed, cotton-seed, cocoanut, rape, groundnut, castor, *sesamum* and *mahua*. Table 13 gives the total exports

of oil seeds, oils and oil seed cakes from India, whilst in Tables 14 to 22 are given the areas under cultivation, the probable total seed crop and the quantities of seeds, oils and oil cakes exported, for the more important varieties. These tables indicate that large quantities of the oil seeds and their products are utilised in the country.

TABLE 13.—*Exports of oil seeds, oils and oilcakes from India.*

Year.	OIL SEEDS.		OILS.		OILCAKES.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Gallons.	£	Tons.	£
1912-13 .	1,217,089	*15,022,009*	24,489,692	*571,945*	161,785	*821,387*
1913-14 .	1,572,792	*17,000,385*	25,991,315	*657,085*	175,313	*920,249*
1914-15 .	946,727	*9,669,897*	30,245,651	*701,357*	136,932	*709,219*
1915-16 .	641,983	*6,582,017*	33,081,357	*812,571*	150,286	*757,501*
1916-17 .	919,853	*10,772,618*	30,904,841	*1,007,151*	124,996	*660,697*
1917-18 .	431,737	*5,052,062*	26,755,953	*1,326,441*	86,159	*471,665*

TABLE 14.—*Linseed*

Year.	PRODUCTION.		IMPORTS INTO INDIA.		EXPORTS FROM INDIA.	
	Area under cultivation.	Yield of seed.	Quantity.	Value.	Quantity.	Value.
	Acres.	Tons.	Tons.	£	Tons.	£
1910-11 .	3,742,400	571,300	...	...	...	...
1911-12 .	5,038,000	664,900	...	...	...	...
1912-13 .	4,124,900	542,100	398	*4,572*	354,489	*5,318,383*
1913-14 .	3,031,000	386,200	596	*5,047*	413,873	*4,457,998*
1914-15 .	3,325,000	397,000	2,191	*22,093*	321,576	*3,502,411*
1915-16 .	3,333,000	476,000	718	*7,017*	192,987	*1,982,782*
1916-17 .	3,532,000	520,000	112	*974*	394,103	*4,759,907*
1917-18 .	...	...	36	*312*	140,676	*1,716,552*

TABLE 15.—*Imports and exports of linseed oil.*

Year.	Imports.		Exports.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
1912-13	364,961	*56,401*	106,867	*20,823*
1913-14	439,482	*58,817*	102,360	*17,493*
1914-15	360,484	*49,781*	132,796	*27,869*
1915-16	267,687	*43,555*	280,850	*47,274*
1916-17	134,922	*29,570*	178,257	*32,830*
1917-18	62,995	*18,042*	557,663	*127,178*

TABLE 16.—*Exports of cotton seed, cotton seed oil and cotton seed cake.*

Year.	Cotton seed.		Cotton seed oil.		Cotton seed cake.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Gallons.	£	Tons.	£
1912-13 . .	130,563	*685,127*	2,324	*318*	7,006	*35,778*
1913-14 . .	284,326	*1,416,743*	2,507	*347*	10,425	*48,157*
1914-15 . .	207,789	*1,004,521*	12,471	*1,059*	6,854	*31,660*
1915-16 . .	95,663	*445,077*	43,030	*4,031*	5,108	*23,452*
1916-17 . .	39,630	*203,940*	84,018	*9,979*	3,903	*15,489*
1917-18 . .	1,627	*9,056*	76,444	*9,621*	200	*800*

TABLE 17.—*American cotton seed production in 1911.*

Total seed crop	5,175,000	tons.
Seed worked up	4,106,000	tons.
Oil produced	168,000,000	gallons,
Oil cake and oil meal produced.	1,792,000	tons.

N.B.—For the same year (1911) the exports of cotton seed from Egypt were 800,000 tons.

TABLE. 18.—*Rape and mustard seed.**

Year.	Area under cultivation.	Yield.	Exports of seed.	Exports of oil.
	Acres.	Tons.	Tons.	Gallons.
1912-13	5,955,800	1,241,200	217,800	414,217
1913-14	6,266,400	1,087,500	249,000	407.178
1914-15	6,507,000	1,219,200	96,900	413,189
1915-16	6,437,000	1,102,100	95,200	465,735
1916-17	6,440,000	1,181,200	121,700	574,328
1917-18	...	...	59,100	488,771

* In 1912 the United Kingdom imported 187,000 quarters of rapeseed and in the same year France 66,000 tons (in addition to about 50,000 tons produced in the country) and Germany 125,700 tons. Pure mustard oil does not appear to be produced in India, the seed being as a rule pressed mixed with rape seed.

TABLE 19.—*Sesamum.*

Year.	PRODUCTION.		EXPORT OF SEED.	
	Area under cultivation.	Yield.	Quantity.	Value.
	Acres.	Tons.	Tons.	£
1912-13	4,989,500	474,000	77,800	*1,215,783*
1913-14	5,076,000	403,500	112,200	*1,796,841*
1914-15	5,565,000	551,000	46,700	*711,885*
1915-16	5,170,000	501,000	13,700	*164,170*
1916-17	...	...	83,700	*1,083,723*
1917-18	...	...	16,000	*225,000*

TABLE 20.—*Groundnut.*

Year.	Production.		Export of ground-nuts.	Export of ground-nut oil.	Export of ground-nut cakes.
	Area.	Yield [nuts in shell].			
	Acres.	Tons.	Tons.	Gallons.	Tons.
1912-13 . . .	1,366,400	669,900	243,350	227,053	62,396
1913-14 . . .	2,105,900	748,800	277,907	288,190	62,026
1914-15 . . .	2,413,000	947,000	138,322	223,363	64,374
1915-16 . . .	1,673,000	1,058,000	175,443	372,538	81,514
1916-17 . . .	2,317,000	1,147,000	143,794	982,253	54,325
1917-18 . . .	...	...	118,152	...	49,900

TABLE 21.—*Castor.*

Year.	Exports of castor seed.		Exports of castor oil.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Gallons.	£
1912-13	110,630	*1,092,177*	954,495	*90,285*
1913-14	134,888	*1,336,649*	1,007,001	*92,504*
1914-15	82,815	*773,289*	898,269	*83,550*
1915-16	87,948	*802,185*	1,451,655	*129,301*
1916-17	92,447	*957,201*	1,723,469	*174,110*
1917-18	86,101	*1,017,373*	2,086,038	*255,560*

TABLE 22.—*Exports of Mahua or Mowhra seed.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	13,293	*112,913*
1913-14	33,298	*263,634*
1914-15	7,437	*50,674*
1915-16	4,215	*24,327*
1916-17	4,239	*26,480*
1917-18	*Nil*	*Nil*

N.B.—Figures for exports of oil and cake are not available.

The figures given in table 13 and also those given in the tables for the individual oils clearly demonstrate that in the past the Indian trade has been mainly in the raw material, *i.e.*, oil seeds rather than in the finished products, refined oils and oil seed cakes.

Development of oil seed pressing.

In Europe and America, the oil pressing industry has made rapid progress during recent years. Improved yields of oil from the seeds, obtained by the use of more efficient plant either in the form of hydraulic presses or solvent extraction plant, improvements in the quality of the oil, effected both by greater care in decorticating the seed before pressing, by the regulation of temperature during pressing, by improved methods of refinement after pressing, and by careful scientific control of all the processes have been characteristic of this development. Attention has also been paid to the residues left after the removal of the oil. Certain seeds, such as castor, yield cakes which, owing to the presence of poisonous substances, can be used for fertilising purposes only; other seeds, the most important of which are linseed, cotton seed and groundnut, yield cakes which have a high nutritive value and are largely used for feeding cattle. Improvements have taken place in the direction of manufacturing mixed feeding cakes, and still more recently, of producing a flour of high protein content suitable for human consumption. In America, the production of a cotton seed cake meal has met with success and the flour mixed with wheaten flour is used for making bread. The cake from ground-

would have to be exported; and the possibility of her competing profitably with Europe and America in such export trade needs careful consideration. It is quite possible that the demand for feeding cakes in India might be stimulated and the use of the cakes as nitrogenous fertilisers increased (see Fertilisers, p. 104), but she would always have a surplus for export. The increased use of nitrogenous fertilisers affects not only the question of the possible development of the scientific methods of oil pressing in India, but also the development of a coal tar industry (page 77).

The following is a summary given by E. W. Thompson (J. Soc. Chem. Ind., 1918, *37*,166 R), of the directions in which expansion of the oil seed industry in the British Empire should be encouraged:—

(1) Extraction of the oil by the solvent process, in order to obtain better yields of oil, but without extracting deleterious substances. The process used should not be subject to great fire risk.

(2) Treatment of the residual meal to free it from all traces of solvent and so render it a high-grade cattle food.

(3) Refining of the oils by methods which cause the least possible loss and which will produce the highest grades of edible oils, tasteless and odourless, both liquid and solid.

(4) Utilisation to the best advantage of the by-products of refining, in order to recover the fatty acids free from objectionable odour and from foreign matter, and the transformation of the recovered acids into the finest soaps and other useful merchandise.

(5) The production of high-grade flours suitable for replacing, or mixing with, wheaten flour for making bread.

(6) Treatment of recovered fibres for use in explosives or artificial silk manufacture or of other types of profitable merchandise.

These are directions in which improvements should be made in India. It is possible that the solvent extraction process may not be so suitable for India as for England, but unquestionably improvements in methods of preliminary treatment, of pressing and refining the utilisation of waste products such as hulls, etc., and the manufacture of high-grade soaps, glycerine and candles are subjects worthy of close attention.

Another problem which deserves serious consideration, on account of the high price of *ghi* and its persistent adulteration, is the manu-

nuts, has undertaken the growth of soya bean, and is planting 200,000 acres of land with Indian castor seeds. Castor is also being cultivated in Brazil and the West Indies. All these activities indicate an appreciable increase in the world's supplies of vegetable oils, which should be met with increased demands, if prices are not to fall.

(4) The country *ghanis* entail a relatively small initial expenditure and are cheap to run. The possibility of retaining this method of pressing and of sending the crude oil to central refineries and the cake which is rich in oil, to extraction factories, is also to be remembered.

(5) A large proportion of the oil manufactured at the present time in India is characterised by its high acid value, which indicates a decomposition of the oil into fatty acids, and glycerine, due to the non-destruction of enzymatic ferments present in the seed. The high acid value is met with particularly in the case of groundnut and cocoanut oils and to a less extent in castor oils. It is not uncommon to meet with Indian vegetable oils containing 25 or 30 per cent. of free fatty acids and the purchase of such oils at a low figure and the removal of the free glycerine by water extraction is a commercial possibility. The high acid values of such oils render them liable to rancidity and unsuited for many industrial purposes, and, so long as Indian oils are liable to this defect, they will not find favour in foreign markets. It would be extremely difficult to obtain an oil of standard quality and suitable for export by developing the industry by means of increasing the number of small pressing factories.

On the whole, it is probable that the best method is that of introducing modern plant—Anglo-American and cage presses for certain types of seed, and solvent extraction plant for others, *e.g.*, *Vateria indica.* In such factories careful preliminary treatment of the seed, as regards sorting and decorticating, and suitable refining of the oils would be necessary. The methods of disposal of the resulting cakes or meal require careful attention. Under present conditions, India herself could not make use of all the cakes or meal manufactured, and for a long time, the bulk of such products

would have to be exported; and the possibility of her competing profitably with Europe and America in such export trade needs careful consideration. It is quite possible that the demand for feeding cakes in India might be stimulated and the use of the cakes as nitrogenous fertilisers increased (see Fertilisers, p. 104), but she would always have a surplus for export. The increased use of nitrogenous fertilisers affects not only the question of the possible development of the scientific methods of oil pressing in India, but also the development of a coal tar industry (page 77).

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Another problem which deserves serious consideration, on account of the high price of *ghi* and its persistent adulteration, is the manu-

facture in India of pure vegetable substitutes for *ghi*, more or less of the nature of European and American margarines.

Linseed oil.

Linseed is one of the most important seeds grown in India, and although the largest producer, she has not a monopoly, as it is also cultivated in Europe, and in North and South America. The area under cultivation for this crop and the total amount of seed available are shown in table 14 (p. 78).

Large quantities of the seed, which contain from 37 to 43 per cent. of oil, are pressed in India and oil of good quality is now readily obtainable. Formerly, large amounts of the oil were imported; this was due both to the superior quality and the lower price of the imported oil. The latter was largely owing to the good price fetched by the cake in Europe, whilst in India the market for this is limited, and the price of the oil has also to cover the value of the cake. In tables 14 and 15 (pp. 78 and 79) are given figures for the imports and exports of the seed and oil. The imports of seed are mainly from countries such as Persia where presses are not available.

Raw and boiled linseed oil, the latter being made by heating the oil to a temperature of 150° in the presence of substances such as litharge, are used mainly in the manufacture of paints and varnishes. for which purpose the oil has hardly a competitor. Its use in the paint industry is due to its valuable property of hardening and drying when exposed to the air, especially in the presence of driers. The oil from the soya bean, which is indigenous to China, Manchuria and Japan, is also a drying oil and is largely used in America for making paints. Although inferior to linseed oil, it is frequently used as a substitute when the price of linseed oil is high. It is also frequently used as a substitute for cotton seed oil. The cake obtained from the presses has a high nutritive value.

Cotton seed oil.

The cotton seed oil industry in India is still in its infancy, although attempts at developing it have been made in Bombay. Cotton seed oil is expressed in Great Britain, but the industry has been brought to a high state of development in America. The area under cotton in India has varied from 25,023,000 acres in 1913-14 to 17,967,000 acres in 1915-16, which means that, if all the seed were worked for oil, some 200,000 tons of oil would be available. Much of the seed is, however, at the present time fed direct to cattle as food.

In America, prior to pressing, the seed is decorticated and a practically colourless oil which requires very little refining is obtained. It is also essential that the seeds should be pressed as soon as possible after ginning, as they rapidly deteriorate, and this is one reason why the American oil is superior to the British. This deterioration of Indian and American "uplands" seeds on storage is mainly due to the lint retaining moisture, which facilitates bacterial fermentation. The heat produced by this fermentation induces hydrolysis of the oils and the liberation of free fatty acids. The fermentation is intensified when broken or damaged seeds are present, as they so frequently are (on the average about 8 per cent. in Indian seed) owing to careless ginning. As Indian seeds differ not only from Egyptian black or "naked" seeds, but also from the American "uplands" seeds, the preliminary treatment such as delinting and decorticating may require special types of machinery. So far but few attempts have been made with Indian seed to reach the high degree of efficiency obtained in the treatment of American seed.

The oil obtained from Indian seeds is, as a rule, not of the same high quality as that from Egyptian or American seeds and the costs of refining are therefore higher. The oil content of the Indian seed is somewhat low, being about 18 per cent. as compared with the American 23 per cent., but the efforts now being made for improving the standard of Indian cotton may also raise the oil content of the seed. The high-grade oil obtained in Europe and America is used mainly as an edible oil in place of olive oil and also in the manufacture of butter substitutes, whilst lower grades are used for the manufacture of soap. The by-products obtained from cotton seed pressing are of great value, the hulls being used as a cattle food and the meal as a wheat substitute.*

In table 16 (p. 79) exports of cotton seed, cotton seed oil and cake are shown, whilst for the purposes of comparison a few American figures are given in Table 17.

Rape oil (colza oil).

Rape oil is widely grown in European countries, but India is probably the largest centre of production in the world. The area under cultivation and the quantity of seed available is shown in table 18 (p. 80).

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* For summaries of cotton seed products see Journal Society Chemical Industry, 1917, 36, 685; 1918, 37, 118 T and 166 R.

The seed contains from 42 to 45 per cent. of oil, which is either obtained by expression or solvent extraction, the latter method which is not in use in India to any considerable extent, being said to yield the purer oil. The oil is mainly used for edible purposes, for anointing the body and as a lubricant. Small quantities are also used for illuminating purposes and for soap making. The cake is an excellent cattle food. The exports of both the seed and the oil are very large and are also shown in table 18 (p. 80).

Sesamum oil.

Sesamum oil, which is also known as til or gingelly oil, is obtained from the various varieties of sesamum. It is grown mainly in India, although it is cultivated to some extent in Java, China, Japan, Africa and South America. The area under cultivation in India and also the quantity of seed produced is shown in table 19 (p. 80).

The oil which is present in the seeds, to the extent of about 44 per cent., is obtained by cold expression. The Indian oil, owing to lack of care in expression, is usually of poor quality. It is mainly used for culinary purposes and for anointing the body. Very little oil is exported from India, although it is largely pressed. The export of seeds is considerable, since by law in certain countries the presence of this oil is required in all artificial butters. In France the lower qualities are used in the manufacture of soap and for lubrication. The cake is a valuable cattle food. The exports of the seed are also shown in table 19 (p. 80).

Arachis oil (ground-nut oil).

This oil is very widely grown throughout the world. In India it is mainly grown in Madras, Bombay and Burma. The area under cultivation and the approximate yield of the nut is shown in table 20 (p. 81).

To obtain a high-grade oil it is essential for the seeds to be decorticated before expression, whilst the red skin which covers the seed must also be removed. The best oil is then obtained by cold expression. The cold pressed oil is used practically solely as an edible oil, the less pure oils being used for soap making and as lubricants. The press cake is a valuable cattle food, and recently Mr. Mackenzie Wallis in Bombay has shown that it can with advantage be used for mixing with wheat flour for human consumption.

The exports of the oil from India are large and the seeds are also exported to France and the United Kingdom. Prior to export, the seeds are frequently decorticated, but the oil from such seeds

is of little value except for use as a soap stock. The exports of the nut, oil and oil cake are also shown in table 20 (p. 81).

Castor oil.

The oil obtained from the seed of the *Ricinus communis*, castor oil, has become of enhanced importance owing to its extended use in the lubrication of aero-engines. In 1914, England produced 15,000 tons of the oil, whereas in 1918 the figure was 45,000 tons, practically all from Indian-grown seed. India is the main source of the world's supply, although the castor plant is grown to some extent elsewhere. It has not proved possible to obtain exact figures for the area under cultivation, although it is known to be large.

The best oil is obtained from the decorticated seed by cold expression, a lower quality being obtained by expression of the heated seed. The oil, when obtained by cold expression, is used as a high-grade lubricant and for medicinal purposes; the lower qualities are used as lubricants, for the manufacture of transparent soaps, preserving leather and in the manufacture of adhesive gums. When treated with sulphuric acid, it yields what is known as "Turkey red oil" which is largely used in alizarine dyeing and in finishing certain grades of leather. Appreciable amounts of this oil have been made in India during the last few years, but the continuation of the production largely depends upon the future price of sulphuric acid in India.

The cake, an excellent fertiliser, is much used both in India and in Europe; it is valueless as a cattle food owing to the presence of a poisonous compound known as ricinin.

The exports of both the seed and the oil are very large (see table 21 (p. 81).

Cocoanut oil.

This oil is obtained from the fruit of the tree, *Cocos nucifera*, which is cultivated mainly on the West Coast. It is not necessary to deal with this oil here, as there is a separate article on the cocoanut industry elsewhere (see p. 274).

Mowhra seed oil.

Mowhra seed oil obtained from the seeds of *Bassia latifolia* is used largely in India as an edible oil, being a yellow fat which readily bleaches on exposure to the air. Prior to the war, the seeds were exported in large quantities mainly to France, but latterly the export has greatly decreased, see table 22 (p. 82). The cake, which is poisonous, is somewhat difficult to dispose of, since it can only be used as a

fertiliser. The oil frequently contains large amounts of free fatty acids. It is used in India as a substitute for tallow and is also used for external application in the treatment of skin diseases.

The oil from the closely related species, *Bassia longifolia,* which grows in South India is used in the manufacture of chocolates and also for candle making.

There are numerous other oil seeds which are grown in India and which are expressed and used locally. Many of these could, doubtless, find a good market. Amongst the more important, which appear to be worthy of investigation, the following may be mentioned :—hemp seed oil, niger seed oil, sunflower oil, croton oil, rice oil, rubber seed oil, domba oil (*Calophyllum inophyllum*), kokum or goa butter (*Garcinia indica*); malabar tallow (*Vateria indica*), nim or margosa oil, (*Melia azadirachta*), and pongam or hongay oil (*Pongamia glabra*).

VI.—Essential Oils.

The East is usually regarded as the source of some of the most important scents and spices. In India occur many of the raw materials from which scents in the form of volatile or essential oils are manufactured.

The following list gives the names of 14 oils quoted in the Monthly Market Report of the Perfumery and Essential Oil Record, and obtained from raw materials grown in India and Ceylon :—anise oil, cardamom oil, cinnamon oil, cinnamon leaf oil, coriander oil, East Indian dill oil, ginger oil, sandalwood oil, thymol, vetivert oil, lemongrass oil, palmarosa oil, gingergrass oil and citronella oil. Some of these, such as cardamom, sandalwood, thymol, palmarosa, are obtained from products grown only in India and Ceylon; the others are also obtained from raw materials grown in other countries.

The old fashioned Indian method, a method which is still in vogue in many districts, was to mix the raw material in a fine state of division with water in a copper or iron vessel which was heated over a free fire. In many cases passing steam through the finely divided material yields a better product and is more economical to work, *i.e.*, it requires less fuel in order to manufacture a given weight of oil.

Before 1914, the only oils actually manufactured in appreciable quantities and exported were lemongrass, palmarosa, gingergrass

and citronella. In practically all other cases, the raw materials were exported and distilled in Europe or America. Probably the only reason why the above mentioned oils were distilled in the country was that they are obtained from grasses, and the freight charges of such would be relatively high and the yields diminished during the long journeys. Since 1914, various developments have taken place in the distillation of essential oils.

Sandalwood oil.

The Mysore Government have stopped their annual auction sales of sandal wood and now distil practically all their wood in two factories erected by the Government in the State (see p. 413).

Thymol.

The production of thymol from *ajwan* seed has been taken up by several firms, and at least two of these are producing high-grade thymol crystals comparable with those manufactured in Germany before 1914. The manufacture of thymol in India presents several points of extreme interest. The oil content of the *ajwan* seed varies considerably and the possibility of increasing the percentage of oil and of thymol by greater care in cultivation requires careful investigation. The seeds were distilled in Germany and the thymol sold at a price which covered the costs of the seeds and of distillation, all profits being made out of the sale of the by-products, *viz.*, spent seed, thymene oil and thymol water. The spent seed is an excellent cattle food, but so far has not found much favour in India. The thymene oil is a cheap scent useful for scenting soap, but the demand in India appears to be very limited.

Although India was practically the only country in which *ajwan* (*Carum copticum*) was grown in large quantities in pre-war times, the plant is now grown in several other countries and, in addition, other sources of thymol have been investigated, *viz.*, *Thymus vulgaris*, or a mixed species of thyme, in Spain and *Monada punctata* in America. All these points have to be taken into consideration in discussing the probabilities of the remunerative distillation of *ajwan* seed in India in the future.

Lemongrass oil.

Much of the lemongrass oil exported on the West Coast has a dark colour and a relatively low citral content and hence fetches a low price on the European markets. A firm in Cochin is erecting special stills for refining much of the dark coloured oil before it is exported.

Citronella oil.

The chief source of citronella oil was Ceylon, but appreciable quantities are now being distilled in Burma and exported.

Palmarosa oil.

It has been shown that the yield of Palmarosa oil can be increased appreciably by substituting steam distillation for the old process of boiling with water.

Cardamom oil.

Attempts have been made to develop the distillation of cardamoms and although oil of excellent quality has been produced (see Perfumery and Essential Oil Record, 1918, 9, 31), the demand for the oil on the European markets does not appear to be sufficient to justify large scale distillation.

Attempts have also been made to distil in India dill oil, the essential oil from *Hardwickia pinnata,* and several other oils. It is highly probable that various other oils might be distilled with profit in India. The cus-cus roots from certain districts in India appear to yield a high-grade vetivert oil, an oil of high price and the basis of most high-grade perfumes. On the Nilgiris, a certain amount of leaves of *Eucalyptus globulus* are distilled for the production of eucalyptus oil. It is highly probable that the distillation might be extended and improved and also that other species of eucalyptus oil might be grown for distillation purposes.

Worm seed oil.

A considerable amount of the Indian variety of *Chenopodium ambrosiodes* has been grown in Assam and the oil distilled. It is being used as a substitute for thymol in hook-worm disease.

The whole subject of essential oil and perfume manufacture requires much more careful consideration than it has received. The possibility of improving the yields and the qualities of the oils by suitable cultivation, the distillation of certain raw materials at present not used to any appreciable extent, the cultivation of plants known to give essential oils, but hitherto not cultivated in India, the best methods of isolating the oils and the best type of plant to use in each case, the processes of extraction and *enfleurage* and the refining of the oils and perfumes are all of them problems which call for scientific treatment. (For a summary on Indian Essential Oils see Journal of the Indian Institute of Science, 1918, Vol. II, p. 13.) Table 23 shows the export of some of the raw materials used in the essential oil industry.

TABLE 23.—*Exports of raw materials for essential oils.*

No.	Article.	Unit.	1912-13		1913-14		1914-15		1915-16		1916-17		1917-18	
			Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity	Value.	Quantity	Value.	Quantity.	Value
				£		£		£		£		£		£
1	Ajwan seed .	cwt.	21,650*	*6,135*	9,784	*2,983*	7,868	*2,736*	13,062†	*4,871*	11,093	*4,304*	3,960	*2,735*
2	Aniseed .	cwt.	2,478	*1,978*	1,129	*931*	835	*977*	594	*615*	3,030	*3,140*	1,578	*1,065*
3	Cardamoms .	lbs.	266,971	*37,765*	878,401	*49,994*	418,135	*54,369*	482,764	*49,597*	204,984	*30,852*	716,358	*64,740*
4	Cinnamon .	lbs.	39,650	*1,018*	38,170	*1,016*	39,711	*869*	54,147	*1,141*	66,045	*1,356*	55,554	*1,064*
5	Coriander seed	cwt.	84,587	*35,477*	95,533	*39,090*	84,051	*46,327*	90,104	*70,953*	84,885	*66,212*	116,273	*80,154*
6	Cummin seed	cwt.	20,130	*30,682*	19,026	*29,338*	13,554	*25,698*	20,308	*12,889*	28,992	*83,207*	18,439	*54,778*
7	Cummin seed, black.	cwt.	1,738	*1,870*	1,313	*1,157*	1,411	*985*	2,050	*1,857*	2,024	*2,761*	3,379	*5,030*
8	Dil or sawn seed.	cwt.	1,920	*1,294*	2,090	*1,489*	1,945	*351*	3,380	*2,342*	9,382	*6,649*	33,813	*28,781*
9	Ginger .	lbs.	9,950,000	*158,425*	9,214,471	*122,661*	7,520,188	*87,291*	6,280,690	*71,351*	5,076,358	*81,522*	5,841,374	*87,254*
10	Sandalwood .	lbs.	..	*101,529*	..	*128,626*	..	*35,918*	..	*103,796*	..	*126,016*	..	*56,644*
11	Citronella oil	lbs.	1,384,628	..	1,586,005	..	1,425,050	..	‡1,674,692	..	..	..	..	..
12	Lemon grass oil.	gls.	32,262	*47,416*	47,522	*67,955*	27,796	*37,914*	31,700	*30,102*	34,993	*32,044*	26,871	*25,613*

* Only 772 cwt. to British Empire.
† 3,882 cwt. to British Empire.
‡ 506,000 lbs. to British Empire.

N.B.—(*a*) The amount of Palmarosa and Gingergrass oils produced each year averages 150,000 lbs., and about 100,000 lbs. are exported.

(*b*) It must not be assumed that the whole of these exports are used for distilling essential oils. The demand for cardamon oil is comparatively small and only a fraction of the total exports is distilled. The same holds good for ginger and cinnamon. The bulk of these are used as spices and flavouring materials and in addition are used for making tinctures.

VII.—Alkaloids.

The alkaloids are basic substances extracted from certain plant tissues and find their chief use in medicine. The quantities required are not large, but when pure they fetch a relatively high price which should cover the costs of collection and extraction.

India is extremely rich in plants containing alkaloids of commercial value, and its great variety of climates renders it suitable for the extended cultivation of alkaloidal plants. Up to the present, only two products from which alkaloids are obtained, namely, cinchona and opium, have received any detailed attention. In both cases, the cultivation of the necessary plants and the extraction of the alkaloids have been undertaken by Government.

Quinine.

The fascinating history of the introduction into India of the cinchona plant and of its subsequent cultivation in the Nilgiris and in Bengal has been adequately described elsewhere (Watt's Commercial Products of India, p. 302), and every effort is still being made to extend the area under cultivation in order to meet the increasing demands. The present area is about 5,000 acres, whilst the output of quinine and its salts from the factories is shown in table 24. The supply is, however, unable to meet the demand and, as will be seen from the following (Tables 25 and 26) considerable quantities of quinine and its salts are imported.

TABLE 24.—*Output of Quinine and salts from the Bengal and Madras Quinine factories.*

Year.	Quinine Sulphate.	Cinchona Febrifuge.	Quinoidine.	Residual Alkaloids.	Cinchonidine.	Cinchonine Sulphate.	Quinine Hydrochloride.	Quinine Hydrochloride acidum.	Amorphous Cinchona alkaloids.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Bengal.									
1915-16 . .	41,814	1,395	1,429	640	..	..	..	..	..
1916-17 . .	20,903	..	1,400	..	118	123	..	..	..
1917-18 .	29,417	8,518	1,261	930	50	..	..	..	..
Madras.									
1915-16 . . .	32,688	..	..	..	..	..	260	50	50
1916-17 . . .	52,518	..	..	..	..	..	1,775	2,191	..
1917-18 . . .	55,014	..	84	..	..	..	1,727	..	..

TABLE 25.—*Imports of Quinine and its alkaloids (including cinchona and Peruvian bark).*

Year.	Quantity.	Value.
	Tons.	£
1912-13	47	*71,509*
1913-14	52	*102,441*
1914-15	31	*85,178*

TABLE 26.—*Imports of Quinine and Quinine salts and Cinchona bark.*

Year.	QUININE AND QUININE SALTS.		CINCHONA BARK.	
	Quantity.	Value.	Quantity.	Value.
	Tons	£	Tons.	£
1915-16	43	*109,509*	0·09	*201*
1916-17	21	*107,017*	0·32	*97*
1917-18	29	*105,660*	2·0	*165*

Morphine.

The extraction of opium and the manufacture of morphine is now undertaken at the Opium Factory, Ghazipur, and recent research by Mr. Annett and his collaborators has much improved the processes in use.

Strychnine and brucine.

Ranking next in importance is the alkaloid strychnine, which, mixed with brucine, occurs in *Strychnos nux vomica* to the extent of 1·5 per cent. Prior to the war, the seeds were exported mainly from Bombay, Madras and Cochin and extracted in Great Britain and elsewhere, but recently attempts have been made to carry out the extraction in India. As the process of extraction is comparatively simple, it is hoped, that when times once more become normal and plant and technical assistance are more readily obtainable, the export of the seed will cease, its place being taken by the purified alkaloids.

TABLE 27.—*Exports of nux vomica (strychnine).*

Year.	Quantity.	Value.
	Tons.	£
1912-13	2,076	*14,408*
1913-14	2,307	*17,366*
1914-15	1,658	*14,556*
1915-16	2,961	*30,760*
1916-17	2,807	*30,537*
1917-18	1,962	*25,329*

Figures for the import of the alkaloids strychnine and brucine are not available.

Caffeine.

Caffeine, a valuable drug used in certain types of neuralgia and kindred diseases, is present in tea, and, to a small extent, in coffee. It is occasionally made from tea damaged during transit, but usually from what is known as "waste tea" which consists mainly of tea fluff, or the hairs of the leaf buds of the tea plant. These accumulate in considerable quantities during the manufacture of tea. Some idea of the extent of the caffeine industry may be gathered from the fact that, in 1912-13, two and three quarter million pounds of this material were exported from India.

Tea fluff is an extremely bulky substance, and the freight charges from India to the countries where it is used for making caffeine are proportionately large. The process of manufacture of caffeine is not complicated, and there seem to be few reasons why it should not be carried out in this country. Perhaps the greatest objection lies in the fact that about half the exports of waste tea are to the United States; and attempts to send the finished article to the same destination would be subject to heavy import duties. In spite of these difficulties, however, it should be possible to make caffeine in the country of its origin.

Experiments are now in progress at the Indian Institute of Science to devise simple means whereby at least the first operations of caffeine manufacture could be carried out in the tea factories themselves. The impure extract might perhaps then be sent to

a central factory to be finally purified. The quantity of caffeine in various samples of fluff is also being determined. Taking an average of 2 per cent. and the price of fluff in 1913 as 1·2 annas per pound, 100 lbs. of fluff, worth 120 annas, would yield 2 lbs. of caffeine worth in 1913 about fifteen shillings a pound or 360 annas, so that there is evidently an appreciable margin for profit even with a poorer grade of fluff than that mentioned.

Atropine and scopolamine (hyoscine).

The Belladonna or solonaceous alkaloids are medicinally of great importance, two alkaloids being prepared in a pure state as a rule, namely, atropine and scopolamine (hyoscine). The three chief sources available are *Atropa belladonna*, *Datura stramonium* and *Datura meteloides*.

Atropa belladonna.—This herb is a native of the Western Himalaya from Simla to Kashmir. The medicinal portions of the plant are the leaves and dried roots.

Datura stramonium.—This plant grows in the temperate Himalaya regions from Baluchistan and Kashmir to Sikkim. The seeds are used as the source of the alkaloid. D. *fatuosa* which grows in tropical districts may also be used.

Datura meteloides.—This plant is found chiefly in the North-West Himalaya and mountains of the Deccan.

It appears probable that the best source of scopolamine (hyoscine) would be the *D. meteloides* (*cf.* Carr and Reynolds, Journ. Chem. Soc., 1912 101, 946). It is separated from the seeds by percolation with alcohol (90 per cent.), the alcohol removed under reduced pressure and the alkaloid separated by crystallisation of the residue from chloroform, in which it is more readily soluble than the other alkaloids of the group.

It is very doubtful if atropine occurs as such in any plant. It is formed by treating the alkaloid hyoscyamine with very dilute alkali. The roots of the leaves of either *A. belladonna* or *D. stramonium* are extracted with cold alcohol (90 per cent.) and, after the removal of the solvent under reduced pressure, the alkaloid is dissolved in dilute mineral acid. The impurities (fats, etc.) are removed by agitation with chloroform, the acid liquid made alkaline with ammonia, the alkaloid extracted with chloroform and from this solution the hyoscyamine is precipitated with light petroleum.

The *A. belladonna* can also be used for the preparation of the alcohol and liquid extracts of the British Pharmacopœia.

Cocaine.

The source of this extremely important alkaloid is the leaves of the *Erythroxylon coca*. Experiment has already shown the possibility of cultivation in the Nilgiris, Assam and Sylhet and it has further been shown that the crystalline alkaloid can be extracted in India.

There are other alkaloids which might possibly prove to be of economic value.

Bebeerine.

Bebeerine occurs to the extent of from 2 to 3 per cent. in the bark of the *Cissampelos pareira* and is mentioned in the British Pharmacopœia. It might be worth extracting on a small scale and there appears to be little difficulty in the preparation.

Colchicine.

The drug "colchicum" which is obtained in Europe from *Colchicum autumnale* is of very considerable medicinal value. It has been shown that *Colchicum lutrum* which grows in the Western Himalaya contains, like *C. autumnale*, the alkaloid colchicine and it is possible that it might be used in place of the latter as a source of "colchicum."

Nicotine.

Recently solutions of the alkaloid nicotine have found considerable use as insecticides. The alkaloid is obtained from waste tobacco by mixing it with lime and steam distillation.

It is hoped that the proposed formation of a Drugs Manufacture Committee will stimulate the cultivation and manufacture in India of these and of other alkaloids of medicinal value such as the aconites and emetine.

VIII.—Natural Dyes.

Before the introduction of aniline dyes, the natural dye industry was one of considerable importance, but the tendency has been for the synthetic largely to replace the natural dye. This replacement has been due to two causes, one the low price at which the aniline dyes could be marketed, and the other the much greater varieties in shades and tints which could be obtained. The question of the relative fastness of natural and synthetic dyes is one frequently discussed, and the opinion is commonly expressed that synthetic dyes are far inferior in this respect to natural dyes. This view is quite erroneous. Many coal tar dyes are not fast but, on the other hand, some are much faster than any natural dyes. Well known examples are the new sulphur dyes and the indanthrene

blues, which are even faster than indigo. Some vegetable dyes are quite fast, *e.g.*, indigo, but others, *e.g.*, safflower and annatto, are extremely fugitive on cotton.

The enormous increase in the price of coal-tar dyes immediately after the beginning of the war, raised the hopes of many people in India that a development of indigenous dyes would take place, and, that even after the war, such dyes would be able to compete with synthetic dyes. Very little, however, has been done. The experiments made by Dr. Marsden were not promising, (Report to Government of Madras, 1916) and it must be clear to everyone that after the war the prices of coal-tar dyes will probably be lower than in pre-war days. Before the war, Germany had practically a monopoly for many classes of dyes, and could fix her own prices. The war has lead to the development of a very big coal-tar dye industry in America and quite considerable developments in England, France, Italy and Japan, so that in the future the competition between these countries for new markets will be keen and prices for some time will be low.

It is estimated that in 1917 forty-six million pounds of dyes were manufactured in the United States, a quantity about equal to the total imports of dyes prior to 1914. In the same year, Japan produced about ten million pounds of dyes.

One serious difficulty with which certain types of natural dyes have to contend is the climatic one. This is very well illustrated in the case of indigo which is obtained as an annual crop. In the days before synthetic indigo was introduced, the profits of the indigo planter were considerable and his financial position was such that the occasional failure of the crop did not mean disaster. At the present time, when the natural indigo can only just compete with the synthetic product, the loss of one year's crop may mean the difference between profit and loss for a considerable number of years.

India is extremely rich in natural dyes but it is doubtful if, apart from indigo, cutch, safflower, turmeric, annatto and red sanders wood, any one of them finds more than a local use.

Indigo.

Indigo is, of course, of outstanding importance and the desirability of reviving once more the cultivation of this dye has been clearly recognised. If the natural product is to be able to compete with the synthetic dye much research will be necessary on the best conditions for its

cultivation, extraction and marketing. The investigations of the indigo research chemist, Mr. W. A. Davis, (Indigo Publications, Pusa, No. 1—4) have already met with considerable success. He has shown that much heavier crops can be obtained by the use of suitable fertilisers (phosphates), whilst he has also succeeded in placing the dye on the market, in a form which enables it to compete more readily with the synthetic dye. Of great importance also have been Mr. Hutchinson's researches on the bacteriology of the processes taking place in the vat. The area under indigo cultivation had largely increased since the outbreak of war, but the failure of the rains this year and a falling demand have caused a considerable set back.

TABLE 28.—*Indigo—area under cultivation and exports.*

Year.	Area.	Exports.	
		Quantity.	Value.
	Acres.	Tons.	£
1911-12	274,476	......	.....
1912-13	227,046	593	*146,755*
1913-14	169,221	547	*141,938*
1914-15	145,792	857	*599,691*
1915-16	351,265	2,096	*1,385,795*
1916-17	770,000	1,677	*1,382,931*
1917-18	710,600	1,456	*957,985*
1918-19	300,700	......	......

Cutch.

Cutch, which is obtained from the red heart wood of *Acacia catechu*, a tree growing throughout India, still finds considerable application as a dyestuff. It is largely used for obtaining various shades of brown,

olive, grey, drab and black and can be used for both animal and vegetable fibres. Its use on wool is, however, restricted owing to its rendering the fibre harsh. It gives excellent results with silk. As a cotton dye, it can hardly compare for fastness with the mineral khaki dye. Of the remaining natural dyes, red sanders wood (*Pterocarpus santalinus*) and sapan wood (*Caesalpinia sappan*), a type of insoluble red woods, are still used to some extent in indigo dyeing, whilst turmeric (from the tubers of *Curcuma tinctoria*) and safflower (the dried florets of *Carthamus tinctorius*) are used for producing mixed colours in cotton dyeing generally with a chrome or a aluminium mordant. Annatto (from the pulp surrounding the seeds of *Bixa orellana*) is used to colour foodstuffs.

Locally, many other woods such as the *Morinda citrifolia*, *Rubia sikkimensis*, *Ventilago madraspatna*, etc., are still used, but they are not of any real commercial value, nor are they likely to become so in competition with the synthetic dyes.

IX.—Disinfectants and antiseptics.

Disinfectants may be divided roughly into two groups, inorganic and organic disinfectants.

The chief members of the first group are, sodium and potassium permanganate, bleaching powder, hypochlorite solutions and boracic acid, whilst in the second group we have formaldehyde, the chloramines and the acid constituents of coal tar, carbolic acid and the cresols.

Permanganates.

The manufacture of sodium permanganate, the solution of which is well known as Condy's fluid, should offer little difficulty, since manganese dioxide is obtainable in large quantities at a low price and the method of preparation is comparatively simple. The manufacture of the potassium salt at a reasonably low cost may offer more difficulty, as, with the exception of saltpetre, potassium salts are not obtainable in India in appreciable quantities. The cost of permanganates will also be dependent on the price of sulphuric acid, which is required for their preparation.

Bleaching Powder.

Consideration of the figures given in following table shows that the imports of bleaching powder and bleaching materials into India are very great.

TABLE 29.—*Imports of bleaching powder and bleaching materials.*

Year.	Bleaching powder.		Bleaching materials.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1912-13	...	...	2,967	*23,620*
1913-14	...	...	3,781	*32,586*
1914-15	747	*7,878*	3,697	*33,089*
1915-16	1,021	*17,659*	3,796	*48,052*
1916-17	1,418	*42,089*	5,473	*114,991*
1917-18	1,510	*54,531*	5,012	*139,398*

The powder is used for bleaching textiles and paper pulp, whilst large quantities are also required for the sterilisation of water and for the preparation of hospital disinfectants. For these purposes, it is possible to substitute a sodium hypochlorite solution made by electrolysing, in a suitable apparatus, a solution of common salt. Such bleach liquors are now in use in many mills and in large towns and hospitals, and their use is likely to be extended as they can be easily prepared as required, and as it is also claimed that they are superior to the powder for bleaching fabrics preparatory to dyeing. Their use, however, will be restricted to large concerns, as liquids are always more difficult to transport than solids and the hypochlorite solutions are extremely unstable, a few hours exposure to light sufficing largely to destroy the bleaching properties. Experiments are now being made in Bombay and elsewhere to prepare a more stable bleach liquor. Hence, although hypochlorite solutions will be more and more widely used, especially when the present difficulties of obtaining plant no longer exist, the demand for bleaching powder is still likely to continue.

Bleaching powder is made by treating lime with chlorine and it owes its valuable properties, like sodium hypochlorite solution, to the fact that it readily liberates chlorine,* and so, in the presence

* Chlorine gas compressed in cylinders is also used now for water purification.

of water, produces a oxidising solution which bleaches cloth, etc., and acts as a powerful bactericide. The manufacture in India on a large scale has not as yet been undertaken and cannot be, until a cheap source of supply of chlorine is available. Its manufacture will be subsidiary to the manufacture of caustic soda by electrolysis. As bleaching powder is unstable and does not keep well in hot climates,* it is essential that it should be manufactured in India. When mixed with boracic acid, itself a useful disinfectant, it forms a disinfectant, first used at Edinburgh University, known as "eupad", the aqueous solution of which is termed "eusol." Boracic acid is now being made locally from borax imported from Tibet.

Chloramine T.

Another valuable type of disinfectant which belongs to the organic group, but owes its properties to chlorine, and which has been recently introduced by Cohen and Dakin, is chloramine-T, a halogen derivative of toluene. The raw material required for the manufacture of this substance is obtained by treating toluene with sulphuric acid, and is a by-product in the manufacture of saccharine, the well known sugar substitute. Hence the manufacture of this disinfectant is dependent on the development of the coal tar industry.

Formalin.

Formaldehyde is a gas which is obtained by the oxidation of methyl alcohol, a product of the distillation of wood (see page 119). It is placed on the market in the form of a 40 per cent. aqueous solution, known as formalin, and finds a very considerable application as a disinfectant. It is also used in the preparation of other substances of medicinal value.

Carbolic acid.

The problem of the manufacture of carbolic acid disinfectants such as "phenyle," "lysol", etc., is complicated by the fact that Indian coal tars are extremely poor in acid constituents which are the basis of these disinfectants. They have, since the outbreak of war, been made on a small scale, but the industry is not likely to continue when conditions are once more normal, unless the coal tar industry is developed on a large scale (see page 76).

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* Experiments in the stabilisation of bleaching powder for use in hot climates have been made by Dr. A. N. Meldrum in Ahmedabad and a preliminary note on these experiments will, it is hoped, shortly be published. (See also Journ. Soc. Chem, Ind. 1918, 311 T.)

Imports of disinfectants other than bleaching powder are shown below :—

TABLE 30.—*Imports of disinfectants.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	1,260	25,783
1913-14	1,269	26,394
1914-15	1,254	27,456
1915-16	1,343	35,553
1916-17	1,479	46,717
1917-18	1,571	67,415

X.—*Fertilisers.*

Scientific agriculture insists upon the need for replacing in the soil the mineral constituents removed by the crops, if the yields per acre are to be maintained. The mineral constituents essential for plant growth are potash and nitrogenous compounds, lime and phosphates. One method of replacing these mineral constituents is by the addition of stable manure, but, as this is insufficient in quantity, and not, in all cases, completely effective, an industry of artificial fertilisers has been developed and has already reached enormous dimensions in Europe and America.

Some idea of the extent of the fertiliser industry can be gathered from the fact that the production of the Stassfurt mines in 1913 was over one million tons, calculated as potash (K_2O), and that of this quantity more than 90 per cent. was used for agricultural purposes, and that about 70 per cent. of the total sulphuric acid production in North America, France and Italy in 1912 was used for the manufacture of superphosphates. The quantity of sulphuric acid used in that year for the manufacture of superphosphates for the world's supply is estimated at three and a quarter million tons.

India is essentially an agricultural country and it might be expected to use enormous quantities of fertilisers. That this is not

so is shown by the figures given for the exports of bones (see table 31), ammonium sulphate (see p. 77) and oil cakes (see p. 78).

In the planting districts, the great advantage to be gained by the systematic use of chemical fertilisers for such products as tea, coffee and rubber has long been realised, the urgent need for phosphatic fertilisers in the indigo areas of Bihar and Orissa has been recently pointed out (Davis, Indigo Publications, Pusa, 1 to 4) and the value of fertilisers in increasing crops such as sugar-cane and cotton is beginning to be appreciated in this country. But apart from such special crops, it is correct to say that the ordinary Indian cultivator has not realised the importance of the application of suitable fertilisers to his land. As agricultural education permeates the masses of small cultivators and as the number of agricultural banks and co-operative societies grows, the demands for these fertilisers will increase, but to what extent it is impossible to say.

Phosphates.

The chief phosphatic fertilisers are (*a*) bones in the form of bone meal, (*b*) superphosphates manufactured from bones and sulphuric acid or from the natural mineral phosphates and sulphuric acid and (*c*) basic slag obtained from the iron and steel works.

Table 31, which gives the exports of bones from India for the years 1913-14 to 1917-18, shows that India has a reserve of phosphatic material which she does not utilise.

TABLE 31.—*Export of bones from India from 1913—1918.*

Years.	Quantity.	Value.
	Tons.	£
1913-14	105,413	*522,233*
1914-15	63,975	*319,553*
1915-16	50,636	*235,583*
1916-17	42,042	*216,277*
1917-18	26,679	*102,389*

It is highly probable that with a reduction in the price of sulphuric acid (p. 63) the demands for superphosphates will increase as the price of Indian-made superphosphate will then be much less.

Superphosphate is generally used where a quick result is required and where the crop will permit the use of a relatively expensive manure. Bone meal, which also contains nitrogen, on the other hand, is used where a slow action is required and where an expensive manure is impossible; for example, on coffee plantations. According to Mr. Anstead, the soils in many of the planting districts in South India are acidic and contain very little lime and therefore, as a rule, it is not advisable to use an acid manure like ordinary superphosphate, but basic phosphates of the type of basic slag and basic superphosphates. At the present time, basic slag is largely used on tea and rubber estates and a good deal of it is imported, but the products from the iron and steel works in Bengal and Sakchi should be able to compete with the imported article provided transit charges are not too high. Finely ground mineral phosphates are also employed as fertilisers, but so far have received little attention in India. The general tendency at the present time appears to be to favour neutral or basic, rather than acidic, phosphates as fertilisers (compare Journ. Soc. Chem. Ind. 1917, *36*, 514).

Potash.

The quantity of potash salts used as fertilisers in India is very limited, the main demand being in the jute growing districts. This demand could be met from Indian products. Saltpetre, which would also serve as a nitrogenous manure, and the pre-war price of which was about £15 to 16 per ton, is used to a certain extent. If saltpetre is used instead of sodium nitrate for the manufacture of nitric acid, then the by-product, acid sulphate of potash, after neutralisation with lime or carbonate of potash, would provide an efficient potash fertiliser. A third source could be provided from the dust from blast furnace gases and flue gases from coke ovens, especially if a certain amount of common salt is added to the fuel (see Journ. Soc. Chem. Ind. 1918, *37*, 222 T and 313 R).

Certain vegetable products, *e.g.*, the water hyacinth and cocoanut shells, yield ashes rich in soluble potash constituents, but it is questionable whether the production of potash compounds from these sources could be worked on a commercial scale and meet the competition of German products such as potassium chloride, which sold at £8—10 per ton in London in 1913, and which could probably have been sold at a profit at £5 per ton.

The whole potash industry will be revolutionised by the acquisition by France of the Alsatian potash mines, as the Stassfurt deposits

will then have a serious competitor and prices are certain to fall (compare Journ. Soc. Chem. Ind., 1918, *37*, 292 T.)

Nitrogenous manures.

The common nitrogenous artificial manures are (1) ammonium sulphate, (2) Chili saltpetre (sodium nitrate), (3) nitrolim, (4) oilseed cakes and (5) nitrates mainly calcium and ammonium, obtained from atmospheric nitrogen. The figures quoted in table 13 on p. 78 for oilseed cake exports show that, under present conditions, India produces more cake than she can use. If the oil pressing industry grows, the quantities of cake available will also increase. It has been shown that the yields of sugar from sugar cane crops can be raised appreciably by the use of oil seed cake as a fertiliser, and a consumption of 1 ton of cake per acre of sugar cane would dispose of large quantities of cake as there are two and three quarter millions of acres under cultivation.

The fact that, of the 3,000 tons of ammonium sulphate produced in India at the present time, some 2,000 tons are exported also shows the small demand for this fertiliser. The amount of ammonium sulphate will increase in the near future as the number of by-product recovery coke ovens is increased.

It appears to be clear that at present the demand for nitrogenous fertilisers is not equal to the supplies, and that appreciable amounts will have to be exported for many years. Hence, the erection of electric plants for the production of cyanamide or metallic nitrates from atmospheric nitrogen for manurial purposes is not a commercial proposition, unless it is shown that these can be manufactured in India at a figure, which would admit of their being exported to Ceylon, the Malay Peninsula and the Dutch East Indies so as to compete with European, American or even Japanese products.

For ordinary crops, the system of green manuring so generally adopted appears to give satisfactory results, but there should be an increased demand for ammonium sulphate for paddy cultivation.

It is obvious that the value of a fertiliser depends on the percentage of the valuable constituents—potash, nitrogen, phosphoric acid—present in the manure, and all sales should be made under a guarantee that the percentages of these constituents are not below a stated minimum.

XI.—Minor Products.

Sodium salts.

Reference has already been made to three sodium derivatives, sodium carbonate and caustic soda (see page 68) and common salt (sodium chloride) (see

page 70). Other salts to which attention may be directed are sodium sulphate and sodium silicate.

Sodium sulphate or Glauber's salt is already made in India in considerable quantity. It is obtained as a by-product in the manufacture of carbon dioxide (for soda water), which is prepared by treating sodium carbonate with sulphuric acid. Large quantities are also obtained, according to the Quinquennial Review of Mineral Production (issued by the Geological Survey of India) as a by-product in saltpetre refining in Bihar. It may also prove possible to obtain it from bitterns. Glauber's salt is used largely in cotton mills, in the manufacture of glass and for dehydrating oils such as turpentine.

TABLE 32.—*Imports of sodium sulphate into India.*

Year.	Quantity.	Value.
	Tons.	£
1913-14*	18	*134*
1914-15	304	*1,496*
1915-16	79	*722*
1916-17	259	*2,153*
1917-18	62	*1,168*

* Except Bombay.

TABLE 33.—*Production of sodium sulphate in Bihar.*

Years.	Quantity.	Value.
	Tons.	£
1910-11	22,689	*46,201*
1911-12	17,791	*30,621*
1912-13	17,992	*30,772*

Sodium silicate is chiefly used in soap manufacture as a filling agent. It is prepared by treating sand with alkali under suitable conditions, and it is understood that it is now being made in Bombay

on a small scale. The possibility of its being manufactured on a large scale in India would appear to be dependent on a cheap supply of fuel and alkali.

TABLE 34.—*Imports of sodium silicate.*

Years.	Quantity.	Value.
	Tons.	£
1913-14*	413	2,534
1914-15	483	2,002
1915-16	441	3,909
1916-17	573	4,885
1917-18	527	7,709

* Bengal only.

Potassium salts.

The only potassium compound which occurs in large quantities in India is the nitrate known as saltpetre (see p. 369). Appreciable amounts of this are recovered from old village sites in Bihar and the Punjab. The product obtained from the local refineries always contains at least 5 per cent. of common salt and frequently as much as 20 or 30 per cent. This crude product was exported to France and other countries where it was refined. A certain amount is now being converted into pure nitrate in Calcutta, but it is probable that, with more care and scientific supervision, it would be possible to produce in the local refineries a product containing 99·5 per cent. of potassium nitrate at much the same cost as it takes to produce 80 or 95 per cent. nitrate. Occasional occurrence of potassium salts are found in the Salt Range, but these are too small and irregular for commercial exploitation. Possible sources in the future are (*a*) potash felspar, (*b*) ashes of plants such as the water hyacinth, (*c*) the ash from cocoanut shells, (*d*) the liquors from wool washing, (*e*) the gases from blast furnaces and from the flues of coke ovens (see page 106). It is more probable, however, that acid potassium sulphate, obtained as a by-product in the manufacture of nitric acid, will provide a sufficient source of supply.

The chief salts for which there is a market are potassium carbonate, already made in some quantity, caustic potash, potassium chloride and chlorate.

The carbonate is manufactured in India by igniting the nitrate with loss of the valuable oxides of nitrogen. The process is extremely wasteful and is unlikely to meet with success in time of peace, unless the oxides of nitrogen can be utilised. Small quantities of the chloride have recently been made in Bengal from the ash of the water hyacinth but it is doubtful if this method could compete with the high-grade chloride obtainable from extensive natural deposits in Italian East Africa. The quantity obtainable from the former source is also not unlimited. It is mainly required for use as a fertiliser for jute (*cf.* p. 106).

The manufacture of potassium chlorate would also probably prove remunerative as the demand is likely to increase with expansion of the match making industry.

TABLE 35.—*Imports of potassium salts into India.*

Year.	Potassium Chloride.		Potassium Chlorate.		Potassium Carbonate.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£
1913-14 .	2*	*50*	117‖	*4,301*	...	...
1914-15 .	Figures not available.		70	*2,720*	65	*872*
1915-16 .	10†	*1,615*	56	*9,287*	0·2	*4*
1916-17 .	1‡	*308*	56	*15,880*	...	...
1917-18 .	1§	*196*	113	*24,565*	...	...

* Bengal only.
† Bengal and Burma only.
‡ Burma only.
§ Bombay only.
‖ Except Bombay and Sind.

Magnesium salts. Apart from magnesium carbonate or magnesite (see page 379), there are two salts of magnesium of technical importance, namely, magnesium chloride and magnesium sulphate. These two salts can be obtained readily

from bitterns, the mother liquor remaining after the separation of salt from sea water (see page 72). This source of supply is already being exploited by one firm of chemical manufacturers for the production of magnesium chloride. Their product, however, is not by any means a satisfactory article and frequently contains considerable quantities of other salts. With unlimited supplies of raw material available, there should be, under scientific supervision, little difficulty in placing a pure product on the market.

Magnesium sulphate or epsom salts can also be obtained from the bitterns, but so far this has not been attempted on the large scale. The salt has been made from magnesite by treatment with sulphuric acid, an uneconomic process and one which it will not pay to continue after the war, unless the carbon dioxide can be collected and sold, and unless the sulphuric acid can be obtained at a cheaper rate, as the value of the acid required is greater than that of the salt obtained.

TABLE 36.—*Imports of magnesium salts.*

Year.	Magnesium chloride.		Magnesium sulphate.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1914-15	2,705	*20,036*	1,972†	10,847
1915-16	3,563	*62,205*	412†	7,061
1916-17	1,067*	*18,757*	266†	3,655
1917-18	1,185*	*19,397*	290†	3,824

* Except Bengal and Sind.
† Except Burma and Sind.

Zinc salts.

When the distillation of the zinc concentrates from Burma is undertaken in Singhbhum, the manufacture in India of the various zinc derivatives of technical value could be developed without difficulty. The three most important are zinc oxide or zinc white, mainly used as a pigment, zinc sulphate or white vitriol, used in dyeing, calico printing and in the preparation of paints and varnishes, and zinc chloride. This

last is already being manufactured on a considerable scale, in solution, and about two hundredweights of the anhydrous salt have been prepared in the form of sticks for medicinal purposes. It finds its chief application in cotton mills, for preserving wood, for making soldering solution and is also used as a disinfectant and deodorant and in medicine as a caustic. In the manufacture of white vitriol and also of zinc chloride, crude hydrogen is produced as a by-product and the cost of the salts would be reduced if use were made of this hydrogen. It would not repay to purify it for the purpose of hydrogenating oils, although it could be burnt and used for generating steam or for concentrating solutions. The successful production of these salts depends largely upon the cost of fuel and also of sulphuric and hydrochloric acids.

The imports of these chemicals are given below :—

TABLE 37.—*Imports of zinc salts into India.*

Year.	Zinc Oxide.		Zinc Sulphate.		Zinc Chloride.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£
1914-15 .	301*	*10,608*	6½†	*86*	1,034‡	*19,852*
1915-16 .	333*	*16,254*	2½†	*46*	1,462‡	*65,824*
1916-17 .	342*	*19,363*	4†	*140*	872‡	*47,542*
1917-18 .	...	...	1½†	*50*	1,740§	*169,129*

* Except Bengal.
† Bombay only.
‡ Except Burma and Sind.
§ Except Burma, Sind and Bengal.

The alums. The local extraction of aluminium sulphate and the manufacture therefrom of alums has long been an Indian industry. Aluminium sulphate is extracted from pyritic shale, which is found mainly in the Punjab. The shales contain about 9 per cent. of sulphur, and the aluminium sulphate is extracted by roasting the shale, lixiviating and concentrating the crude aluminium sulphate solution. A mixture of crude chlorides, nitrates and sulphates of sodium and potassium

is then added and the alum crystallised. The product is mainly soda alum and finds its chief market in the Delhi district, where it is used in the tanning and dyeing industries. Crude aluminium sulphate "alum cake" is also being made by several chemical firms in India from bauxite, but unless the present price of sulphuric acid is very much reduced there would appear to be little prospect of this product competing with the imported article. It is largely used for water purification. Alum is also used for paper sizing, and in medicine.

TABLE 38.—*Imports of aluminium sulphate and alum.*

Year.	Quantity.	Value.
	Tons.	£
1912-13	5,054	*31,146*
1913-14	4,504	*28,155*
1914-15	3,657	*25,992*
1915-16	4,636	*45,418*
1916-17	5,704	*73,242*
1917-18	3,733	*76,729*

Lead salts.

With large supplies of lead readily obtainable from Burma the manufacture of the various lead derivatives of commercial value should be an industry capable of considerable expansion. Litharge and red lead, both of value as pigments, are already being made on a considerable scale. The manufacture of white lead probably the most important of all pigments has not as yet been undertaken. The experiments which have been made on this subject by Drs. Sudborough and Watson at the Indian Institute of Science have now practically reached completion, and it is possible that they will shortly be developed on a technical scale. The method adopted is a modification of a German patent and utilises metallic lead and acetic acid as the starting material, with a periodic replacement of small amounts of acetic acid lost in the process.

TABLE 39.—*Imports of red and white lead.*

Year.	Red Lead.		White Lead	
	Quantity	Value	Quantity.	Value.
	Tons.	£	Tons.	£
1913-14	2,191	*50,839*	1,087	*28,068*
1914-15	1,645	*38,348*	1,253	*37,784*
1915-16	1,445	*46,266*	916	*31,656*
1916-17	1,324	*65,695*	901	*46,050*
1917-18	1,286	*80,027*	542	*39,679*

Chromium salts. Owing to the increased demands for chromium for metallurgical purposes, the internal and external demands for chrome iron ore are gradually increasing and the sources of supply being rapidly opened up. The chief deposits of chrome iron ore are in Mysore, Baluchistan and Singhbhum. Attempts on a comparatively small scale have been made to manufacture the various chromium salts, such as sodium and potassium chromates, dichromates and alums, which are of technical importance, being used in chrome leather manufacture and in khaki dyeing. There should be no difficulty in making these products in India, provided cheap fuel, sodium carbonate, and potassium carbonate, are available. For manufacturing sodium chromate, the finely divided ore is roasted in a reverberatory furnace for several hours with lime and sodium carbonate, the resulting mass extracted with water and the aqueous solution evaporated.

Within the last few years, appreciable quantities of chrome tanning liquor have been made in India from imported sodium dichromate, sulphuric acid and jaggery. It should be possible to make products of the nature of 'tannolin' in India.

Lead chromate is also of commercial value as a yellow pigment and could easily be produced, if sodium chromate were manufactured in the country, as it is prepared by precipitating a solution of lead acetate with one of sodium chromate. It is largely used as a pigment and also in calico printing and is the chief constituent of all

the members of the group of chrome yellows, *e.g.*, Cologne yellow, Paris yellow and Leipzig yellow. By mixing with Prussian blue (p. 117), these yellows give the Brunswick greens, and by treatment with alkali various orange and red pigments, *e.g.*, Chinese red and American vermilion. The figures for the imports of these chemicals and the exports of chrome ore are given in the following tables:—

TABLE 40.—*Imports of chromium salts.*

Year.	Sodium Dichromate.		Potassium Dichromate.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1914-15	187*	5,574	103*	4,996
1915-16	352	13,732	163	11,882
1916-17	449*	44,923	65*	11,120
1917-18	820*	75,179	253*	54,328

* Except Bengal.

TABLE 41.—*Exports of chrome iron ore.*

Year.	Quantity.	Value.
	Tons.	£
1913-14	180	9,205
1914-15	183	12,404
1915-16	92	4,922
1916-17	310	10,473
1917-18	748	32,717

Although the imports are comparatively small, the demands for chromium salts for chrome leather tanning are likely to increase, and the manufacture of these salts in India in quantity sufficient to meet the Indian demands and also for export appears to be worthy of consideration.

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1915-16	1,445	*46,266*	916	*31,656*
1916-17	1,324	*65,695*	901	*46,050*
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1915-16	92	*4,92[illegible]*
1916-17	310	*10,473*
1917-18	748	*32,717*

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Iron salts.

The only iron salt manufactured in India on a large scale is ferrous sulphate or copperas, which is prepared by treating scrap iron with warm dilute sulphuric acid. This salt is largely used in dyeing and tanning and in the manufacture of inks, Prussian blue and other pigments. The production in India has developed since the outbreak of war and as a result the imports have shown a large diminution. The success of the manufacture after the war will depend solely on a cheap supply of sulphuric acid being available. The present output is approximately 1,000 tons per annum.

TABLE 42.—*Imports of ferrous sulphate into India.*

Year.	Quantity.	Value.
	Tons.	£
1913-14	724	*2,637*
1914-15	750	*3,287*
1915-16	2,533	*19,944*
1916-17	5,105	*42,173*
1917-18	839	*7,540*
1918-19*	7	*37*

* Six months' figures.

Cyanides and ferrocyanides.

In view of the dependence of the gold mines on an adequate supply of either sodium or potassium cyanide, it would appear to be highly desirable that the manufacture should be undertaken locally. One method adopted is to treat a mixture of sodium or potassium carbonate and charcoal with ammonia gas under suitable conditions (Beilby's method), whilst another is to fuse nitrolim (p. 225) with salt. The latter method, which yields a crude product (30 per cent. sodium cyanide) suitable for gold extraction, might prove the more suitable if the manufacture of nitrolim is undertaken in India.

TABLE 43.—*Imports of cyanides into India.*

Year.	Sodium Cyanide.		Potassium Cyanide	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1913-14	...	...	264	*22,730*
1914-15	55*	*5,140*	207	*18,151*
1915-16	385*	*36,939*	50	*5,021*
1916-17	401*	*41,478*	54	*5,939*
1917-18	349*	*39,182*	2	*592*

* Bombay and Madras only.

It would appear to be very doubtful if the preparation of ferrocyanides could with advantage be undertaken in India. The ferrocyanides are obtained as by-products in gas works, and the price is therefore extremely low. Small quantities of potassium ferrocyanide have been made in India by the old method from horns and old organic matter. This process would not appear to be likely to be remunerative after the war, as the yields are always poor. The ferrocyanides are mainly used for the manufacture of pigments such as Prussian blue.

TABLE 44.—*Imports of potassium ferrocyanide.*

Year.	Quantity.	Value.
	Tons.	£
1914-15	3·8*	*250*
1915-16	0·7†	*112*
1916-17	4·6†	*2,268*
1917-18	6·1‡	*3,073*

* Excluding Burma.
† Bombay and Madras only.
‡ Calcutta, Bombay and Madras.

Acetic acid and acetates.

Ordinary wine vinegar, which contains about 4 to 8 per cent. of acetic acid, has been known from ancient times, and is manufactured by the oxidation of dilute alcoholic solutions by means of atmospheric oxygen in the presence of certain species of bacteria. Such liquids are used only for household purposes, and cannot be employed for manufacturing concentrated or glacial acid, as the cost of concentration would be too great. (Compare, however, Hibbert. Chem. and Met. Engin. 1918, *19*, 397).

The world's chief source of acetic acid is the crude pyroligneous acid produced during the destructive distillation of wood. The crude acid is redistilled, neutralised with lime and the solid calcium acetate, heated preferably under reduced pressure, with sulphuric acid. As the number of wood distillation factories has increased it is probable that after the war the supply of acetic acid and acetates from pyroligneous acid will be large and prices low. (For a general discussion of wood distillation and recovery of by-products see Journal of the Indian Institute of Science, Vol. II, part 7, pages 80-119.)

Numerous experiments have been made in recent years on the production of acetic acid from other sources and a large number of patents have been taken out. A method which appears to have commercial possibilities is the conversion of acetylene made from calcium carbide into acetaldehyde by the addition of water in the presence of small amounts of mercury salts, and the subsequent catalytic oxidation of the aldehyde to acetic acid. This method is of no value in India, unless calcium carbide (see p. 229) is manufactured in the country at a low cost.

Another process consists in passing alcohol vapour and air over a catalyst, such as metallic copper, condensing the acetaldehyde and oxidising this by atmospheric oxygen in the presence of a catalyst. In a hot climate like that of India, the cost of condensing the volatile aldehyde vapour would be a disadvantage.

The oxidation of alcohol to acetic acid by means of sodium dichromate and sulphuric acid and the subsequent recovery of the dichromate by electrolytic oxidation has been studied by Mr. Usher in Bangalore.

Acetic acid is used as a coagulant for rubber latex, and various acetates, more especially those derived from iron, aluminium, chromium and copper, are used as mordants in the dyeing industry. Certain salts are also used medicinally.

Figures for the imports of acetic acid and some of its salts are given in the following table :—

TABLE 45.—*Imports of acetic acid and its salts into India.*

Year.	Acetic Acid.		Potassium Acetate.		Lead Acetate.		Chromium Acetate.		Sodium Acetate.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
1913-14 . .	42	*1,798*	..	..	..	..	..	..	..	..
1914-15 . .	40	*1,832*	..	..	0·8*	*29*	7*	*370*	3†	*63*
1915-16 . .	51	*4,787*	0·5*	*118*	31†	*1,150*	2†	*166*	1†	*52*
1916-17 . .	69	*12,732*	..	..	34†	*2,145*	..	..	..	..
1917-18 . .	45	*9,355*	..	..	162†	*16,520*	..	..	..	..

* Madras only.
† Bombay only.

Methyl alcohol. Crude methyl alcohol, known under the name of wood spirit, is one of the by-products obtained from wood distillation factories. It is usually obtained by neutralising the redistilled pyroligneous acid with lime, and distilling the neutralised liquid in steam heated pans provided with fractionating columns. At present it is not produced in India, but immediately wood distillation plants are installed appreciable amounts should be available. The normal pre-war price in England was Rs. 1-12 per gallon, but in 1918 the price had risen to Rs. 12-8 per gallon. Very large amounts have been produced in Europe and America. The average yearly import for the period 1913-15 into Great Britain was more than half a million gallons.

One of the chief uses of wood spirits is as a solvent, more particularly in the manufacture of spirit varnishes. Enormous quantities are also used as a denaturant for alcohol. The product known as methylated spirit usually contains 90 per cent. of rectified spirits and about *10 per cent. of wood spirits, together with small amounts of such substances as pyridine. Wood spirit is not used as a denaturant in India, probably owing to its scarcity. If manufactured in the country, appreciable amounts might be used for this purpose.

Wood spirits contain acetone and small amounts of various other compounds, in addition to methyl alcohol, and pure methyl

* This amount has been appreciably reduced in several countries during the last year or two owing to the increase in cost of the wood spirit.

alcohol can be obtained from the spirits by suitable chemical treatment.

Methyl alcohol is used for the manufacture of formaldehyde (formalin) see p. 103 and also for the manufacture of various esters and ethers, *e.g.*, the manufacture of methyl acetate and methyl salicylate.

It is claimed that methyl alcohol, together with a little acetone, can be manufactured by the destructive distillation of the concentrated black liquors, obtained as a waste product in the digestion of wood with soda in wood pulp factories (Met. and Chem. Eng. 1917, *16*, 182 and 416).

Oxalic acid and formic acid.

Since the outbreak of war, oxalic acid has been manufactured on a small scale in India by fusing saw dust with caustic soda, whilst a patent for its extraction from "sal" bark, the fibrous bark of *Shorea robusta*, has also been taken out (see Chemical Trade Journal *1917*, 520, Allen Bros. and Company Ltd. and C. F. Cross, *E.P.* 110, 837 of 1917). The lack of a cheap supply of caustic soda and caustic potash has probably retarded any extensive manufacture from sawdust in India. In Europe, it is now as a rule manufactured from sodium formate, which is cheaply prepared by treating sodium carbonate and lime under pressure with power gas rich in carbon monoxide.

Formic and oxalic acids and their salts are used mainly in the dyeing industries, and for medicinal purposes. Within the last few years, appreciable quantities of formic acid have been used in dye works and tanneries owing to the difficulty of obtaining lactic acid.

TABLE 46.—*Imports of oxalic acid and formic acid into India.*

Year.	Oxalic Acid.		Formic Acid.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1913-14	...	...	0·25*	*18*
1914-15	36	*1,637*	2·0†	*80*
1915-16	15	*2,029*	2·0‡	*411*
1916-17	18	*4,359*	0·5‡	*103*
1917-18	62	*12,656*	0·5	*138*

* For Burma and Madras only

† For Bengal and Bombay only.

‡ For Bengal and Madras.

Citric acid.

Citric acid is manufactured from the juice of the lime on a considerable scale in Sicily and America, where limes are cultivated for the extraction of the juice from the pulp and the essential oil from the skins. Experiments, which have been made in India, have shown that the acid content of the juice of the common varieties of the Indian lime have the same percentage content of citric acid, as those of the above-mentioned countries. It would, therefore, appear probable that the manufacture of citric acid could be undertaken with advantage in India, provided that limes were cultivated in plantations for the purpose, and the juice collected in a central refinery, where it could be worked up in large quantities and the essential oil also extracted. A cheap supply of sulphuric acid would also be requisite for success, since the acid is purified by conversion into the calcium salt which is decomposed by the addition of the necessary quantity of sulphuric acid. The imports of citric acid are not large, and it would be necessary to export a portion of the products of the factory.

TABLE 47.—*Imports of citric acid into India.*

Year.	Quantity.	Value.
	Tons.	£
1914-15	8	*2,331*
1915-16	6	*2,185*
1916-17	26	*9,654*
1917-18	33	*12,652*

Tartaric acid.

Tartaric acid is manufactured in Europe from by-products obtained in the manufacture of wines by the fermentation of grape juice. The two chief sources are "argol" or slightly impure potassium hydrogen tartrate which separates as crystalline crusts on the sides of the vats and "lees," which is highly impure potassium hydrogen tartrate mixed with yeast and various other organic substances. The higher grades of argol are usually re-crystallised and thus yield the pure potassium hydrogen salt known commercially as "cream of tartar," whereas the lees and the lower grades of argol are used for manufacturing the free acid.

These sources are not available in India, and the only material which appears to be at all suitable is the pulp of the tamarind fruit. This pulp contains about 12 per cent. of tartaric acid, mainly in the form of the free acid, but partly as the potassium hydrogen salt. Small quantities have been prepared from this source, but its production in larger quantities could only be profitable in normal times, if the pulp could be obtained at an extremely low price. It is possible that its manufacture in Indore, where tamarinds can be bought at about Re. 1 to Rs. 1-5 per cwt., might pay. The pulp, as regards its tartaric acid content, is only comparable with low-grade "lees" as many of these contain 25 to 30 per cent. of tartaric acid and the method of manufacture would probably be similar.

The acid is used medicinally and also in the manufacture of baking powders, effervescent drinks and in dye works.

TABLE 48.—*Imports of tartaric acid.*

Year.	Quantity.	Value.
	Tons.	£
1914-15 .	37	*5,163*
1915-16 .	83	*16,804*
1916-17 .	90	*27,641*
1917-18 .	27	*8,521*

Metallurgical Industries in India.

By Dr. L. Leigh Fermor.
Geological Survey of India.

I.—Introductory.

The first edition of this Handbook contained an article on "Chemical and Metallurgical Industries in India." It has now been decided to discuss the metallurgical industries in a separate article.

Introduction.

Metallurgy is one of the very oldest of the arts, dating back to the successful attempts of early man to replace weapons and implements of stone by those fashioned first of bronze and later of iron. The younger chemistry, on the other hand, is a science developed historically from the searches of the alchemists after the elixir of life and the philosopher's stone; and although with the progress of modern research metallurgy is rapidly passing from an art into a science, so that it may be legitimately regarded as a branch of applied chemistry, yet it is convenient to accord to the metallurgical industries of India the separate treatment justified by history.

The development of metallurgical industries in any country depends to a large extent upon the existence of suitable raw materials. Nearly 300 years B. C., Megasthenes * wrote that India "has under-ground numerous veins of all sorts of metals, for it contains much gold and silver and copper and iron in no small quantity, and even tin and other metals which are employed in making articles of use and ornament as well as the implements and accoutrements of war."

Commenting on this passage, V. Ball in the introduction to his well-known volume on the "Economic Geology of India," published in 1881, writes:—

"To many it may appear that it was a fanciful and fabulous India, very different from the country as it is now known

* J. W. McCrindle, 'Ancient India,' p. 31. Quoted by V. Ball.

to us. To such the facts set forth in this work not only as to the extent of the mineral resources, but also as to the extent of the ancient mining operations, will come almost as a revelation.

"Speaking generally, the value of the majority of the deposits is relative to external circumstances. Were India wholly isolated from the rest of the world, or were her mineral productions protected from competition, there cannot be the least doubt that she would be able, from within her own boundaries, to supply very nearly all the requirements, in so far as the mineral world is concerned, of a highly civilised community. But the consumer would probably have to pay more than he does at the present day.

"Many of the deposits of metallic ores are undoubtedly poor from the point of view of the European miner. Still the native miner and smelter, by an enormous amount of very hard work, were enabled to produce the metals which they sold at very high prices; but the production per man was so small that these artizans managed only to secure for themselves a scanty subsistence. As foreign competition has enabled the merchant to sell the metals at the very mines at a lower price, the trades of the indigenous miner and smelter have been, as regards those who worked all the metals, except iron, almost completely crushed out of existence."

At the time this was written, the only one of the ancient metallurgical industries of India still struggling against the competition of imported products produced by modern methods abroad was the indigenous iron industry, and to this day numerous diminutive native blast furnaces* in the wilder parts of India, particularly in the Central Provinces and Orissa, continue to produce by wasteful methods—wasteful as to consumption both of ore and of charcoal—small blooms of soft iron used chiefly for making axe-heads and plough shares. In addition, in many parts of India, in countless rivers and streams, panning for gold is still practised, mainly by aboriginal tribes, with variable and often inadequate returns.

A study of the ancient workings existent in many parts of the Indian Empire shows, however, that in the past several other metals besides iron were won from the hard rock, being extracted from the ores

* In 1916 in the Central Provinces nearly 4,500 tons of iron-ore were smelted in nearly 300 furnaces.

by crushing and smelting. We may instance the old workings on gold-quartz reefs in Mysore, succeeded after a prolonged period of oblivion, by the modern gold industry of the Kolar field; the old copper workings of Singhbhum, where lodes are now being followed to considerable depths by the Cape Copper Company; and the mining and smelting of silver-lead ores for silver by the Chinese in the Northern Shan States, now succeeded after a lapse of some 50 years by the developments of the Burma Mines, Limited, with its discoveries of large stores of rich silver-zinc-lead ores and silver-copper ores. In addition, the stream tin deposits of Tavoy seem to have been washed and smelted for centuries.

At the time Ball wrote, there were no active metallurgical plants in India operating successfully along modern lines, all attempts at iron smelting having so far proved a failure. In 1885, however, the Mysore Gold Company started its successful career by the discovery of a rich reef below the old workings, and since 1887 the history of the Kolar field has been one of uninterrupted prosperity. But, even by the beginning of the present century, the only metallurgical concerns successfully established in India on modern lines were the gold milling and reduction plants of Kolar and the Barakar Iron Works, which latter after many vicissitudes had at last succeeded in producing pig iron at a profit. During the present century metallurgy in India has taken a sudden step forward, as is shown by the table on the next page of production of metals in India.

In 1903 the Hutti Gold Mines (Hyderabad State) commenced extraction. In 1907, the Tata Iron and Steel Co., Ltd., was registered, and the first production of pigiron by this Company at Sakchi took place in December 1911 and of steel early in 1912, whilst ferromanganese was first manufactured in 1915. In 1918, the Bengal Iron and Steel Co., at the instance of the Indian Munitions Board, turned one of their blast furnaces on to the manufacture of ferromanganese, thus releasing one of the larger Tata blast furnaces for the production of pig iron. In 1909, after several years of preliminary work, the Burma Mines, Limited, commenced smelting old Chinese slags for lead and silver and are now smelting ores for the same two metals. Finally, the Cape Copper Company, after several years of development work, produced in 1917 in a trial run a small quantity of copper matte, and in 1918 started the regular production of blister copper.

TABLE 1.—*Production of metals in India for the years 1901, 1905, and 1908 to 1917.*

Year.	Gold.	Platinum.	Silver.	Copper.	Lead(*a*)	Tin. Metal.	Tin. Ore.	Pig iron. (*b*).	Steel.	Ferro-manganese.
	Ozs.	Ozs.	Ozs.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1901 .	532,126	..	..	..	..	..	82	35,000 (approx.)	..	..
1905 .	631,116	..	4,716 (*c*)	..	91(*c*)	..	76	44,704	..	..
1908 .	567,780	..	..	..	..	..	95	37,692	..	..
1909 .	574,916	..	27,500	..	5,030	..	84	38,634	..	..
1910 .	572,920	..	49,080	..	12,596	75	89	35,933	..	..
1911 .	583,567	37·7	103,850	..	13,135	88	97	49,183	..	..
1912 .	590,354	50·6	93,476	..	8,331	201	175	145,833	..	..
1913 .	595,761	57·7	125,200	..	5,858	182	171	204,112	63,175	..
1914 .	607,888	30·7	236,446	..	10,348	98	270	234,720	86,603	..
1915 .	616,728	17 7	285,387	..	13,235	128	431	241,794	76,355	2,635
1916 .	598,360	0 2	760,874	..	13,790	118	630	244,710	92,902	1,842
1917 .	574,293	3·3	1,531,831	..	16,962	141	666	248,132	114,027	1,475
1918 .	..	..	1,396,212 (*d*)	(*e*)	13,182 (*d*)	..	..	..	..	1,150 *f*

(*a*) Except for 1905, the figures given are the output of the Bawdwin mine, Burma. In addition, in some years, insignificant quantities of lead ore have been extracted in the Southern Shan States, the Drug district, Central Provinces, Kashmir, and the Chitaldrug district, Mysore.
(*b*) Output of the Tata Iron and Steel Co. to end of 1913 distributed as follows :—1912, 87,000 tons ; 1913, 144,025 tons : total 231,925 tons.
(*c*) Yield from 92 tons 16 cwts. of silver-lead bullion sold in London and smelted from a pocket of galena at Beldi in the Manbhum district, Bihar and Orissa, in 1904 and 1905. See *Rec. G. S. I.*, XXXIX, p. 254.
(*d*) To end of August 1918.
(*e*) Production of blister copper commenced August 1918.
(*f*) Monthly output.

It will be seen from the preceding page that the decade 1909 to 1918 has seen the initiation of production in India on a commercial scale of lead, silver, steel, ferro-manganese, and copper. The future offers many further possibilities. We may expect large increases in the production of iron and steel, copper, lead and silver : we may look to the smelting of the zinc concentrates of Burma at present set aside : and our raw materials would permit of a large increase in the scale of production of ferro-manganese and, once cheap electric energy has been rendered available, of the manufacture of other ferro-alloys, such as ferro-chrome and ferro-tungsten, as well as the manufacture of aluminium and calcium carbide. The future of the ferro-manganese industry cannot, however, be regarded as assured on account of the high phosphorus contents of most

Indian cokes, which, combined with the moderately high phosphorus in many Indian manganese-ores, makes it difficult to produce an alloy as low in phosphorus as the foreign market is accustomed to. The gold industry is not likely to show any substantial increase, as far as can be predicted from our present knowledge and information concerning the distribution of gold deposits in India, and, in fact, the output figures at present point to a slight but gradual decrease in output.

The future needs of the country in metals cannot be accurately estimated, but they will, as industries expand, undoubtedly exceed greatly the present consumption, which may be gauged from the following tables of imports and exports of metals into India during the past five years, taken in conjunction with the figures of metals in India given on page 126.

TABLE 2.—*Imports of metals into India for the years 1912-13 to 1917-18.*

(In tons.)

Year.	Aluminium.	Brass bronze, etc.	Copper	German silver.	Iron and steel.*	Lead.	Quick silver.	Solder.	Tin.	Zinc.
1912-13 .	1,790	17,150	6,059	820	729,311	5,717	169	280	1,779	5,598
1913-14 .	1,317	21,796	16,973	1,291	1,018,248	6,220	92	293	2,135	6,740
1914-15 .	777	14,283	12,162	675	608,635	4,646	42	335	1,925	2,220
1915-16 .	772	8.251	3,977	120	424,597	5,792	87	391	1,430	791
1916-17 .	41	3,854	1,125	33	257,079	4,699	52	383	1.430	1,416
1917-18 .	37	2,934	2,406	16	152,049	4,385	71	168	1,273	3,532

* Exclusive of cutlery and hardware, machinery and millwork, railway plant and rolling stock.

TABLE 3.—*Exports of metals from India for the years 1912-13 to 1917-18.*

(In tons.)

Year.	Brass, bronze, etc.	Copper.	Iron and steel.	Lead.	Tin.	Tin ore.	Zinc. †
1912-13 . .	154	200	104,210	7,520	13	214	120
1913-14 .	127	241	84,855	3,493	47	210	7,660
1914-15 . .	94	190	52,800	6,518	21	115	4,900
1915-16 . .	91	51	72,682	10.848	5	87	187
1916-17 . .	228	791	115,444	10,422	1	214	8,214
1917-18 . .	17	122	52,623	10,570	4 cwts.	300	2

* The high figures for 1913-14, 1914-15 and 1916-17 are due to exports of zinc ores and concentrates from Burma having been included under the metal.

II.—Accessory Materials and Electric Energy.

The successful production of metals in any country does not depend solely on the availability of ores of sufficient richness. In addition—leaving out of consideration such factors as market conditions and transport—we require :—

(1) *Reducing agents*—usually some form of carbon (coal, coke, or charcoal), but sometimes electric energy utilised electrolytically;

(2) *Sources of heat*—either carbonaceous fuel or electric energy —to produce the temperature necessary to permit reduction;

(3) *Fluxes*—limestone, dolomite, iron-ore, siliceous materials, and fluorspar—to combine with, and remove into the slags, the impurities of the ores, and to impart the fluidity requisite for successful operation;

(4) *Refractory materials*—sand, fireclay, magnesite, dolomite, chromite, bauxite, and graphite—for lining furnaces and constructing vessels, such as retorts and crucibles, capable of withstanding the high temperatures characteristic of most metallurgical operations, and the corrosive action of the materials smelted;

(5) *Carbon electrodes* for electric smelting processes.

In this section a brief reference to each of the above factors as they affect India must now be given; such an account will serve to indicate to prospectors who have located valuable ore deposits some other materials and conditions that should be investigated.

Reducing agents.

In special cases, special reducing agents are used, *e.g.*, powdered aluminium for the preparation by the Thermit process of molten iron for welding, and of small quantities of the rarer metals, by reduction from their oxides in crucibles. But the only reducing agent we need consider here is carbon, which may be used in the form of either coal, coke, or charcoal. It is the last-named which was used in all the old indigenous smelting processes and which is still used in the small native iron furnaces. In modern practice, however, charcoal has been, wherever possible, superseded by coal or coke, usually the latter, on account both of the greater density and strength of coke, enabling it to stand without crushing the heavy burden of modern blast furnaces, and of the difficulty of obtaining

supplies of charcoal adequate to the scale of modern smelting operations. A simple calculation shows that an attempt to run on charcoal a modern blast furnace producing pig iron would require the allotment of an area of forest—allowing for felling in rotation and replanting—altogether out of proportion to the results obtained. This is partly because the carbon is serving two purposes, namely, as reducing agent and as the source of the necessary heat. In electric smelting, the heat is otherwise provided, so that carbon is required for reduction only. In such cases, in well-wooded countries, the use of charcoal is often economically feasible, and its use has the advantage of introducing into the resultant iron or steel a smaller amount of phosphorus than with most cokes. A project is, indeed, in hand for the establishment in Mysore of electric iron-smelting with charcoal as reducing agent.

In most cases, however, in blast-furnace practice in India the use of coke is imperative. Although the supplies of coal in India are large, only a certain proportion of this is suitable for the preparation of dense, hard, metallurgical coke, and as the coking coals of India are typically high in phosphorus and moderately high in ash, the resultant coke is almost always much higher in these impurities than good English cokes. The high ash contents can, of course, be neutralised in the furnace by suitable fluxing, but the phosphorus finds its way into the metallic product. For this reason, Indian pig iron is phosphoric, so that the basic process has to be adopted in the production of steel. For the same reason, added to the somewhat high phosphorus contents of most Indian manganese-ores, it will prove exceedingly difficult to produce in the blast furnace in India ferro-manganese with phosphorus not greater than 0·30 per cent, the upper limit usually accepted in Europe. With electric smelting and charcoal fuel accompanied by a careful selection of ores, this figure could, however, be realised. In the manufacture of calcium carbide in the electric furnace the same difficulty will arise; for whereas we shall probably be able to find sufficiently pure limestone,* the provision of a coke sufficiently low in phosphorus (and in ash) will offer considerable difficulties. Good metallurgical coke is also required in lead and copper smelting.

There is indeed no doubt that the future welfare of the smelting industries of India would justify a careful survey and classification

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* See table of analysis, p. 231.

of the coking coals of this country with reference to physical characteristics, ash contents, and phosphorus.

Coal as such is used as a reducing agent in zinc distillation processes, but, as the zinc is distilled off, the impurities in the coal do not affect the quality of the product. Coal is sometimes used as such, mainly as a source of heat, in metallurgical processes, especially in reverberatory furnaces, where the gaseous products only come into contact with the ores, so that the impurities in the coal do not affect the quality of the product.

Sources of heat.

The heat necessary for the conduct of most metallurgical operations is usually provided either by the heat of combination with oxygen of the carbon of the fuel used, or in electric smelting by the conversion of electric energy into heat on overcoming the resistance of the charge. The question of the use of coal, coke, and charcoal in India as reducing agents has already been considered in the previous subsection. Except in electric smelting, this carbonaceous reducing agent also acts as the provider of heat, and remarks already offered as to supplies and impurities in the fuel used apply equally at this point.

In special cases, with highly pyritic ores, the necessary heat is provided by the combustion of sulphur. Pyritic smelting has not yet been introduced into India, but in the bessemerising of copper matte in Singhbhum the heat necessary for the maintenance of the reaction is provided by the oxidation of the sulphur of the matte by the air blown in. In the Thermit process, the heat developed represents the heat of combination of aluminium with oxygen.

The future development of metallurgical practice may, in certain cases, lead to the use of oil fuel, and in such cases India's needs should be amply satisfied from Burma, the Punjab, and Abadan in Persia.

But the great advance of the future in dry metallurgical practice—as distinguished from wet metallurgical practice involving the use of solutions and acids, such as gold cyaniding and electrolytic refining—seems to lie in electric smelting. In its initial developments India is following the well-trodden paths of ordinary furnace practice, but on account of the existence of valuable ores in parts of India remote from the coalfields, consideration must be given in the future to the possibilities of electric smelting. These possibilities cannot be accurately evaluated until the completion of

at least a preliminary hydrographic survey* of India; but we know of the existence of vast resources of water power in the Western Ghats; in addition, the capabilities in this respect of the Assam Plateau, the Nilgiri Hills, the Central Provinces, Central India, and Burma, all seem promising and need careful investigation. Provided such water power can be converted into electric energy at a sufficiently low price, we may expect one day to see the electric treatment in India of the iron-ores of Mysore, Goa, and Ratnagiri, the manganese-ores of the Sandur Hills, the bauxites of the Western Ghats, Central Provinces, and Chota Nagpur, the wolfram of Tavoy, the chromite of Mysore, and finally the copper-ores of Sikkim (hydro-electrically), as well as the manufacture of calcium carbide.

The conditions that will render electric energy suitable for use in metallurgical processes are a continuous day and night supply, throughout the year if possible, delivered at a sufficiently low price at a site suitable with respect to transport conditions both for the assemblage of raw materials and for the despatch of finished products to markets. As an index to the price of energy permissible, it may be mentioned that for calcium carbide it should not exceed 0·10 annas per unit or £3·65 per k. w.-yr. and for aluminium £5 per k. w.-yr. Some other electric smelting processes might be able to stand a somewhat higher price.

In connection with electric smelting, consideration must also be given in special cases to the possibilities of generating electricity cheaply from coal, both *viâ* the Mond-gas process and with steam-electric plant.

Fluxes.

In the treatment of ores with an acid (siliceous) gangue, basic fluxes are required, and of these limestone, dolomite and iron-ore—of all of which India possesses vast stores in many geological formations at various localities—are those commonly used. At present, the Tata Iron and Steel Company is using dolomite from Panposh in Gangpur State, and the Cape Copper Company limestone from Bisra in Gangpur and iron-ore from near Manharpur in Singhbhum. The Burma Mines Limited for their lead smelting are using as basic fluxes limestone, with iron-ore from the Northern Shan States and from Mandalay. A preliminary survey of Indian limestones as regards suitability for the manufacture of calcium carbide is now in progress. We also require information concerning the distribu-

* See also page 145.

tion and composition of Indian limestones and dolomites from the point of view of fluxes and cements, and there is no doubt that a careful and elaborate investigation of these matters would justify the necessary expenditure of time and money. Fluorspar is sometimes used in furnace practice for increasing the fluidity of the charge, as for example in the steel furnaces at Sakchi, the quantity so consumed in 1916 being 200 tons. But unfortunately no fluorspar deposits of any size have yet been located in India, and this mineral has therefore to be imported.

Refractory materials.

The refractory materials required by modern metallurgical procedure are numerous and varied, but it is doubtful if there is a single material of this nature that cannot be provided from the wide resources of the Indian Empire, although at present no sand entirely suitable for furnace bottoms has yet been found. Siliceous materials (sand, sandstone, quartzite, and quartz) are used for the manufacture of silica bricks, for lining furnace bottoms, and as moulding and casting sands (not to mention their use in the manufacture of pottery and glass); and for various purposes attention is being directed towards the sometimes very pure saccharoidal quartzites of Dharwar age (*e.g.*, in the Kharakpur Hills, Monghyr), and to Vindhyan sandstones, which vary in purity, and amongst which we may be able to find varieties analogous to the English ganister. Silica bricks are now being manufactured in continually increasing numbers by Messrs. Burn and Company, and by the Kumardhubi Fireclay and Silica Works, Limited, and are pronounced to be equal in quality to some, and superior in quality to other, imported bricks. Fireclay suitable for the manufacture of firebricks is obtainable from the shales of the Gondwana formation, *e.g.*, at Raniganj, and good firebricks are now manufactured on the "Bengal" coalfields by Messrs. Burn and Company, by the Kumardhubi Fireclay and Silica Works, and by the Reliance Fireclay and Pottery Company, Limited; and at Jubbulpore by the Perfect Pottery Company, Limited. Fireclay will also be required for the manufacture of zinc-distillation retorts when this industry is installed in Singhbhum. As a basic lining for furnaces magnesite and dolomite are both used. Excellent magnesite, raw or calcined, is forthcoming from Salem, whilst the Tata Iron and Steel Company is now being supplied with magnesite bricks made from the Company's Mysore magnesite by the Kumardhubi Fireclay and Silica Works.

Where a neutral lining is required, either chromite or bauxite may be used. Chromite exists in commercially valuable quantities in Baluchistan, Mysore and Singhbhum, and chromite from Mysore is being used by the Tata Iron and Steel Company at Sakchi at the rate of 65 tons a month as a neutral material for separating the acid roof from the basic hearth in the open-hearth steel furnaces. Bauxite of good quality exists in many parts of India and can easily be rendered available when required.

Carbon electrodes.

The establishment of electric smelting in India will necessitate a supply of carbon electrodes. At first these will doubtless be imported, but electrodes should eventually be manufactured in India. The specially pure carbon required for this purpose cannot at present be obtained. Petroleum coke would be suitable, but the processes of oil refining adopted in Burma do not yield any appreciable quantity of this substance. Similarly, the Oriental Gas Company, Calcutta, uses a process of distillation which avoids the production of retort carbon, another suitable material for our purpose. The future expansion of the iron and steel industry in India will, however, necessitate a great increase in coke production, in great part, doubtless, with by-product recovery. Since Indian coal yields about 2 per cent. of tar, large quantities of coal tar will therefore be rendered available. Indian coal tar on distillation yields a high percentage of pitch (a test on Kulti tar gave a yield of 58 per cent. of pitch), which would serve as the chief ingredient in the manufacture of carbon electrodes. This manufacture in India may thus be regarded as bound up with the installation of tar-distilling plants on a considerable scale.

III.—Metals and Alloys.

Statistics as to production of metals in India with figures of imports and exports are given on pages 126 and 127. We may now review briefly in alphabetical order the metallurgical industries of India, both as to their present condition and immediate possibilities. In addition to the metals specifically referred to below, small quantities of ores of arsenic, bismuth, cobalt, molybdenum, tantalum, and uranium and of others of the rarer elements have been found in India.

Aluminium.

The annual consumption of aluminium in India is comparatively small, and any works erected to smelt this metal would at first be compelled to

dispose of a portion of its production by export. But there is no doubt that ultimately India will become a very large consumer of aluminium.

The conditions for the manufacture of this metal in India appear to be very favourable. Large stores of bauxite exist in the Jubbulpore and Balaghat districts, Central Provinces, in the hills of Chota Nagpur west of Ranchi, and possibly on the Western Ghats. The success or otherwise of such an industry depends upon the provision of sufficiently cheap electric energy. The production of the metal involves the manufacture of refined alumina as an intermediate product, which would also serve as the raw material for the manufacture of alum and other aluminous compounds.

Antimony.

Antimony is a metal of some importance for munitions. The industrial uses for this metal and its compounds are legion, of which some of the most important are as metal for hardening alloys, as sulphides for the match industry and vulcanising rubber, and as tartrate and oxalate in calico-dyeing and printing. Hitherto, only small quantities of antimony-ore have been extracted in India; but deposits are known to exist in the Mong Hsu State, Southern Shan States, and in the Amherst and Thaton districts, Burma. The two latter have recently been visited by officers of the Geological Survey of India* and Mr. Heron reports that although the stibnite deposits at Thabyu in the Amherst district are very difficult of access, being near the Siamese frontier, yet the quantity of ore seems to be considerable, so that the property offers a reasonable prospect of remunerative working. Successful experiments have been made in the production of regulus and metal from Thaton ores, but the quantity of the latter hitherto proved appears to be small. The Burma Mines Limited produces as a by-product an antimonial lead running 15 to 16 per cent. in antimony, which is suitable for use as an antimony-lead-alloy, *e.g.*, for shrapnel bullets. In addition to supplying alloy of the above composition to the Indian Ordnance Department, the Company exported, early in 1918, 450 tons of antimonial lead containing 13·4 per cent. of antimony with some copper and silver.

The present requirements of India in this metal are unknown, as the import figures are not recorded separately in the Annual

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* *Rec. G.S.I.*, XLIX, p. 13.

Statements of the Sea-borne Trade and Navigation of British India, but they must amount to at least 300 to 400 tons per annum, with about 100 tons of type metals.

Copper and brass.

The consumption of copper and brass in India is considerable—of the order of 25,000 to 35,000 tons annually. The Cape Copper Company Limited has for some years been engaged in opening up the Matigara mine (now known as the Rakha Hills Mine), Singhbhum, and in July 1917 the ore reserve stood at 407,641 tons, averaging 3·71 per cent. copper over a width of 42 inches. Complete milling and smelting plant have been installed, capable at present of producing refined copper at the rate of about 1,000 tons per annum, and with an enlargement of the blast furnace from three to five water jackets, the scale of production will increase to about 1,800 tons of metal annually. The ore is enriched in the mill to about 9 to 10 per cent. copper, which in a trial in December 1917 gave matte running 55 per cent. copper. In August 1918, the first Bessemer converter was put into operation and blister copper produced. The plant is now ready for continuous operation, once the difficulty of obtaining adequate supplies of coke at the present time of stringency has been overcome.

Prospecting operations are being conducted at various other localities along the 80-mile copper belt of Singhbhum, and the future may see the opening up of additional copper mines in this district. There are also workable bodies of copper-ore at the Bawdwin lead mines in the Northern Shan States, and a production of copper from this source may be expected in the future. The possibilities of the Sikkim copper deposits have not yet been satisfactorily determined, but should they prove workable, a hydro-electric process may be used for their treatment based on power from the Teesta.

With the establishment of a zinc-smelting industry in India, the production of brass from indigenous materials will also become possible.

A considerable amount of scrap copper comes on to the Indian market every year, and experiments carried out at the suggestion of the Board at Bangalore and Patna show that the refining of this scrap electrolytically offers no technical difficulty.

Ferro-manganese and other ferro-alloys.

There are numerous deposits of manganese-ores, chrome-ores and wolfram in the Indian Empire, and once cheap supplies of electric power become available, the possibility of producing ferro-mangan-

-ese, ferro-chrome and ferro-tungsten in electric furnaces in India must be seriously considered. Such alloys would of course have to be exported in the main to foreign markets.

Meanwhile the production of ferro-manganese by the more customary blast furnace methods has already been successfully inaugurated. On account of the great increase in price of ferro-manganese due to the war, one of the blast furnaces of the Tata Iron and Steel Company at Sakchi was turned on to the manufacture of ferro-manganese in October 1915, and up to the end of that year 2,658 tons of alloy were made of the following average analysis :—

	Per cent.
Manganese	65—75
Phosphorus	0·6—0·8
Silicon	2—0·60

Subsequently the average composition of the ferro-manganese produced was :—

	Per cent.
Manganese	70
Phosphorus	0·55—0·66
Silicon	2—3

the average output from one furnace being about 80 tons a day. The production of ferro-manganese at Sakchi has been discontinued on account of the necessity of keeping both blast furnaces on the production of pig iron, required for the manufacture of steel. But from the end of 1917 one of the smaller blast furnaces of the Bengal Iron and Steel Company at Kulti has been producing ferro-manganese with a guaranteed minimum of 70 per cent. manganese and not exceeding 0·55 per cent. phosphorus, from ores derived from the Central Provinces. The average monthly output of alloy is 1,150 tons, and the balance left over after satisfying the requirements of Sakchi is exported, the total exports (to France, United States of America, Italy, and Natal) up to the end of August 1918 being 7,555 tons.

The phosphorus contents of the alloy produced at Sakchi and Kulti were considerably higher than the figure 0·30 per cent. representing the upper limit of phosphorus acceptable abroad in normal times. With a very careful selection of Indian ores (*e.g.*, ore from Balaghat with 0·07 phosphorus) and the use of Giridih coke running

only 0·022 phosphorus, ferro-manganese could be produced with phosphorus within this figure. But considering the facts that the amount of Giridih coke is limited and that the percentage of phosphorus in Indian manganese-ores is slowly but steadily increasing with depth from the surface, it is evident that India can never be a large producer of low-phosphorus ferro-manganese by blast furnace methods. The possibilities of the electric production of low-phosphorus ferro-manganese deserve therefore careful consideration.

Gold.

From time immemorial the river gravels of India have been washed for gold, mainly by primitive castes and tribes who combined this pursuit with other occupations. The gold is absorbed locally by jewellers and although complete returns of production are naturally not obtainable yet the quantity of gold so won cannot now exceed a few hundred ounces annually. For some years, the Burma Gold Dredging Company has been recovering a few thousand ounces of gold annually by dredging the gravels of the upper reaches of the Irrawaddy, a small amount of platinum being also recovered. But during the past few years the output has fallen off greatly and in 1917 only 1,006 ounces were obtained, so that the operations have now been discontinued.

By far the greater portion of the gold won in India is obtained from quartz reefs worked by modern methods of underground mining, chiefly in Mysore, but to a small extent in Hyderabad (Deccan), Anantapur, and Dhalbhum. In almost every case, the location of the present mines was determined by the existence of old workings where people of by-gone days had mined the upper portions of the reefs and then abandoned them, doubtless in part due to the increasing difficulty of extracting ore and water with increasing depth, but perhaps in part due to political causes.

We need refer here only to the Kolar Gold Field.* The original companies were floated in 1881-82, and as the features of the auriferous deposits were not at first grasped much money was wasted in mining in barren ground and amidst ancient workings, which were found to extend to a depth of 300 feet. By 1885 all the companies were moribund, when a dying effort of the Mysore Company disclosed the great richness of the reef and the disposition of the ore in chutes. By 1887, the adjacent companies had resumed opera-

* *Rec. G.S.I.*, XXXII, p. 46.

tions and since then the history of the field has been one of uninterrupted success. The deepest workings are now some 4,000 feet below the surface and we have in the Kolar Field some of the deepest mines in the world, developed on thoroughly efficient lines under the able management of Messrs. John Taylor and Sons. Five mines are now working, namely, Mysore, Champion Reef, Ooregum, Nundydroog, and Balaghat, all employing the same general methods of extraction. The auriferous quartz is crushed with water in stamp batteries and the pulp passed over amalgamated copper plates, where the coarser gold is collected. The tailings are then classified into sands and slimes, which, in some cases, after re-grinding the sands in tube mills are treated in vats with cyanide solutions for the recovery of a further portion of the gold. From these solutions, the gold is precipitated by means of zinc shavings and the black slime after further treatment is smelted in pots and refined. The methods employed in the recovery of gold by cyanide treatment are interesting as an example of the employment in India of wet methods of metallurgy, as contrasted with the dry or furnace treatment employed in the extraction of all the other metals hitherto produced.

It will be seen from the figures on page 126 that the average annual production of gold in India is about 600,000 ounces, which is worth about £2,300,000. The Kolar Gold Mines in the 36 years since the commencement of work under European supervision have yielded gold to the value of nearly £49,000,000 (to the end of 1917).

Iron and steel.

For several decades the attempts to introduce into India European processes for the manufacture of pig iron and steel led to conspicuous failures, and for a brief account of these attempts, starting with the efforts of J. M. Heath in 1830 at Porto Novo in South Arcot, reference may be made to the *Records of the Geological Survey of India*, Vol. XXXIX, p. 101.

The now successful Barakar Iron Works was originally established in 1875, and passed through various vicissitudes of fortune, being taken over by the present company, the Bengal Iron and Steel Company, Limited, in 1889; but it was not until 1899, under the present Managing Agents, Messrs. Martin and Company of Calcutta, that a profit balance was shown. The annual production of pig iron at the beginning of the present century was about 35,000 tons. An attempt to make steel resulted in a heavy loss on this section

of the plant in 1905 and 1906, amongst the causes of the failure being

(1) the low price of imported steel at that time,

(2) the fact that the orders received were for small quantities of steel of numerous sections instead of being confined to larger orders for a few sections,

(3) the inferior quality for steel-making of the pig iron then produced, and

(4) the necessity then existing of importing all firebricks and ferro-manganese.

In 1910, the Company commenced to draw their supplies of iron-ore from a new source, namely, Pansira Buru, and Buda Buru, some 12 miles from Manharpur in Singhbhum, and from this date commenced a new era in the history of the Company. The plant now includes four blast furnaces each capable of producing about 80 tons of pig per day; of these furnaces, one has been diverted to the manufacture of ferro-manganese. The total annual output of pig iron for the years 1915 to 1917 approximated to 90,000 tons. This pig is in part consumed in the Company's foundries, etc., in part marketed in India, and in part exported to Japan, Australia, South Africa, etc. The coke-ovens are fitted with plant for the recovery of the by-products, tar and ammonia, the latter being converted into the fertiliser ammonium sulphate. The sulphuric acid is made at the works in a modern plant, producing about 5 tons of acid daily, and the monthly yield of ammonium sulphate is about 95 tons.

The Tata Iron and Steel Company, Limited, which was registered in 1907, began to produce pig iron in December 1911 and mild steel early in the year 1912; and after a somewhat anxious period, whilst overcoming the various difficulties that so often attend the initial stages of enterprises planned on a large scale, the works have now been placed on a thoroughly sound footing and have proved invaluable to the prosecution of the war by providing large quantities of rails and sleepers for military railways in Mesopotamia, Palestine and East Africa and even for the Salonika front. An account of the development of this Company, its present plant, and projected future extensions, is given in a separate article in this handbook by Mr. Tutwiler, General Manager of the Company (see page 401).

Reference has been made above to the discovery of the new iron-ore deposits owned by the Bengal Iron and Steel Company

at Pansira Buru and Buda Buru in the Saranda forests of Singhbhum near Manharpur. This discovery, due to the late Mr. R. Saubolle, prospecting on behalf of Messrs. Martin and Company, may be destined to rank as an epoch-making discovery in the history of the Indian iron and steel industry. With these deposits as a starting point, subsequent prospecting has led to the discovery of what appears to be a range of iron-ore. forming a definite geological stratum in the Dharwars of Singhbhum. At present it has been visited by the Geological Survey of India only at its northern end (Pansira Buru), but judging from the accounts of reliable geologists in private employ, the iron-ore range. rising to heights of 2,000 to 3,000 feet above sea-level (*i.e.*. roughly 1,000 to 2.000 feet above the adjoining valleys), runs almost continuously for 40 miles in a S. S. W. direction from near Pansira Buru through Saranda into the Keonjhar and Bonai States of Orissa. This iron-ore range has been largely staked out by the Bengal Iron and Steel Company, the Tata Iron and Steel Company. the Indian Iron and Steel Company (Messrs. Burn and Company). and Messrs. Bird and Company. The Pansira Buru deposit, recently visited by me, shows a body of high-grade hematite (limonitised at the surface), about 400 feet thick and 1,300 feet long, with a steep dip, down which the deposit has been exposed by quarrying operations for some 500 feet. The ore-body plunges to an unknown depth and the ore, according to the Bengal Iron and Steel Company, averages on analysis :—

Iron	64·00
Silica	3·00
Manganese	0·06
Phosphorus	0·05

Further, I am informed by Mr. Judd of the Tata Iron and Steel Company that at one place on one of the concessions of the Tata Company, a ravine cutting across the iron-ore range shows a continuous thickness of some 700 feet of hematite running over 60 per cent. in iron.

An officer of the Geological Survey of India has been detailed to make an examination of the whole iron-ore range, and if his examination and the results of future development work confirm the present ideas as to the magnitude of this discovery, it is evident that India may be regarded as provided with reserves of high-grade iron-ore commensurate with as large an expansion of her iron and steel

industries as may be justified by the requirements not only of India but of surrounding eastern markets.

When one remembers the existence of vast deposits of limestone in Gangpur State to the west and the proximity of the most important coalfields of India, it seems probable that future developments in iron and steel smelting in India will be concentrated in or near Singhbhum. These probabilities, combined with the actualities of Sakchi, the successful inauguration of copper smelting by the Cape Copper Company, and the arrangements to smelt the Burmese zinc concentrates in Singhbhum, not to mention such smaller enterprises as those based on the apatite, chromite, wolfram, ochre, and clay deposits of this district, make it evident that Singhbhum is destined to become the metallurgical centre of India. This certainty would justify Government in taking all measures in advance to provide for a scientific organisation of the district as regards administration, communications, and sanitation.

Whilst the production of iron and steel by the well-established methods of smelting with coke as the source of heat is bound to centre in Singhbhum, the question of producing electric steel and ferro-alloys in Mysore is receiving attention, and should a large hydro-electric scheme be installed near the West Coast, as is proposed, the question of smelting the hematitic ores of Goa would also be worth consideration.

The possibility of treating the low-grade magnetites of Salem has been examined, and it is evident that these quartzose magnetic ores, like the magnetite-apatite-rocks of Singhbhum, will, unless smelted in admixture with other ores, be suitable for treatment as iron-ores only after magnetic concentration and briquetting.

Lead.

Small deposits of galena have long been known to exist in various parts of the Indian Empire, but it is only in this century that attention has been given to the possibilities of the old silver-lead mines of Bawdwin in the Northern Shan States. These mines were worked by Chinese from Yunnan for some centuries and deserted about 50 years ago. The Chinese extracted a portion of the lead with the bulk of the silver and left large heaps of zinc-lead slags carrying a little silver. Modern work was commenced on these deposits by the Great Eastern Mining Company, Limited, in 1902, one of the first tasks undertaken being the construction of a light railway to connect the mines with Manpwe station on the Burma Railways,

The property was eventually sold to the Burma Mines Railway and Smelting Company, Limited (now the Burma Mines, Limited), and in 1909 the first production of lead and silver, mainly from slags, took place. In 1914, the control of the Burma Mines, Limited, was assumed by the Burma Corporation, Limited. Development below the old Chinese workings has led to the recognition of four main ore bodies, three of which are composed of complex argentiferous lead, zinc, and copper ores. On June 30th, 1918, the ore reserves then developed stood at 4,279,888 tons, assaying 26·8 per cent. lead, 18·7 per cent. zinc, 0·7 per cent. copper, and 24·2 oz. silver per ton. In 1917, the production amounted to the substantial figures of 16,963 tons of pig lead and 1,580,557 ounces of silver, whilst the production for the first eight months of 1918 has been 13,182 tons of lead and 1,396,212 ounces of silver, giving monthly averages of 1,648 tons and 174,526 ounces respectively. When present extensions are completed, the annual capacity of the plant will be, refined lead 31,500 tons; silver 2,475,000 ozs.; zinc concentrates about 25,000 tons. Further extensions are proposed for the future.

On completion of the mill the ores will be classified into lead and zinc concentrates, the flotation process being used. At present lead-ores, after roasting, are run through a blast furnace with limestone and iron-ore as fluxes and Jharia coke as fuel and reducing agent. The hard lead from the blast furnace is then re-melted in a reverberatory furnace known as the improving furnace, a dross containing copper, nickel, and arsenic with some silver being removed from the surface. The purified lead is run into another smaller furnace, worked at a higher temperature, where antimonial dross is removed. The resultant lead from the antimony furnace is then de-silverised by the use of zinc, and the silver crusts purified by the distillation of the zinc followed by cupellation to remove the lead.

As by-products the antimonial dross is treated to yield an antimonial lead with 10 to 20 per cent. of antimony, which is marketed as such, a copper-lead matte, and a nickel speiss, which are being stored, presumably until the accumulation of sufficient quantities to justify treatment.

By referring to the tables of production, imports and exports, on pages 126 and 127 it will be seen that by 1916 India had become self-supporting in respect of lead. The monthly production of the Bawdwin mines has now reached a figure of over 1,600 tons a month

which, if maintained, would correspond to an annual output of nearly 20,000 tons. This is more than sufficient to satisfy the demands of India and Ceylon, which are about 15,000 to 16,000 tons yearly, chiefly for the manufacture of tea-lead, but partly for ordnance purposes, and for sheets, pipes, solder and other alloys.

The Burmese pig lead, though of high-grade, is not pure enough for making sheets for some chemical purposes, such as the manufacture of sulphuric acid; but it has been found possible by further treatment to produce lead of the requisite degree of purity and it is proposed to use such lead for the sulphuric acid plant being erected in Singhbhum in connection with the scheme to smelt the Burmese zinc concentrates at Sakchi and recover the sulphur as acid.

Nickel.

Nickel is the only metal of primary importance for munitions purposes of which adequate supplies of ore have not yet been located in India. Not only is this metal required for munitions purposes, but also for the new one-anna and two-anna coins, which are composed of an alloy of nickel and copper. Nickel is also used in the preparation of German silver, of which there is a small annual import into India (see page 127). As noticed under lead, a small quantity of nickel may one day be forthcoming as a by-product from the smelting of the Bawdwin ores.

Platinum.

There has been a very small annual production of this metal, recovered by the Burma Gold Dredging Company from the Irrawaddy gravels above Myitkyina. This company has now, however, ceased work. Platinum is also said to have been found in gravels in the Chindwin and Hukong rivers. The ultra-basic rocks containing the chromite deposits of India may, any of them, prove to contain platinum, and considering the great scarcity of this metal throughout the world, it might be worth while testing the gravels and sands in streams originating from such ultra-basic rocks. The physiographic conditions in the saxonite massifs of Baluchistan in which the chromite deposits occur are so favourable for the accumulation and discovery of platinum, should it exist in the parent rocks, that a search there is very desirable. One test carried out by the Baluchistan Chrome Company at my suggestion gave, however, a negative result.

Silver.

India is well known as the largest consumer of silver in the world and is often referred to as the "sink" for silver, for a large proportion of the metal

that comes into this country gets locked up in the form of jewellery and as hoarded coin. The net annual imports of silver during the quinquennial period 1904-08 was over 94,000.000 ounces and during the succeeding quinquennial 1908-13 over 81,000.000 ounces. But in spite of India's traditional wealth in silver this country has never, as far as is known, been a producer of this metal, except in trivial quantities. The opening up of the Bawdwin lead mines is therefore a matter for some satisfaction on account of the rapidly increasing output of lead and silver, the yield of the latter metal rising from 27.500 ounces in 1909 to a rate of production in 1918 that promises a total of over 2,000.000 ounces. The proposals for the extension of smelting facilities at Namtu will give a daily production of 21,000 ounces of silver or some 7.000.000 ounces of silver yearly.

A small amount of silver (512 ounces in 1915, 1,362 ounces in 1916 and 1,281 ounces in 1917) is won from the Anantapur Gold Mines.

Tin. From the statistics of imports and exports it will be seen that India does not yet produce all the metal required for internal consumption. She is, however, likely to do so in the future and in any case can always satisfy her requirements from her neighbour the Federated Malay States, which is responsible for some 43 per cent. of the world's output of this metal. Such metal as is smelted in Lower Burma is produced in small furnaces of a primitive type.

With the proposed installation of mills for rolling steel plates at Jamshedpur (Sakchi), the production of tin-plate in India seems a probability of the near future.

Zinc. Hitherto India has produced no zinc, being entirely dependent upon foreign supplies. It is now proposed to erect at Sakchi plant for the smelting in India of a portion of the zinc-sulphide concentrates of Bawdwin, on a scale of 70 tons a day of concentrates running 48 per cent. zinc and 30 per cent. sulphur, with a production of 29 tons of spelter and 90 tons of chamber acid, equivalent to about 10,000 tons of spelter and 32,000 tons of acid per annum. The latter will, of course, be of great value in promoting the chemical development of India, whilst the establishment of zinc smelting will render possible the proposed production at Sakchi of galvanised iron sheets.

The Future of Hydro-Electric Power in India.*

By J. W. Meares, M.I.C.E..
Electrical Adviser to the Government of India.

Sources of power.

The chief sources of power in the world (exclusive of animal power) are fuel, water and wind. The sun is of course the ultimate source in all four cases, and on an experimental scale solar heat has been directly utilized for the generation of steam. More usually, however, either the fuel, which solar action caused to grow in primeval forests, or the water, which is daily raised by evaporation to fall again by gravitation, or the wind which results from variations of temperature, is harnessed for the needs of mankind. Wind power and sun power are too precarious and variable to be used on any but a small scale, and water power does not always exist where it is wanted. Consequently the world's industrial development depended, until recently, upon fuel through the agency of the steam engine. Latterly the steam turbine and the oil engine and gas engine have taken up their share of the burden, while simultaneously the advances in electrical transmission have enabled progressive countries to develop their water power. Fuel supplies are not unlimited, and unless the factory is brought to the coal or oil field the fuel must be carried to the factory—or at least within reach of transmission of power. Unless the facilities for such carriage are exceptionally good it is found more economical to transmit the power than to carry the fuel. Mechanical transmission is practically limited to a few miles, and although there are considerable possibilities in the intermediate device of converting fuel into gas for pipe transmission it is established that for long distances electricity is the only method of transmitting power. There are losses in any case, whether in the form of actual power wasted in heat, or of annual capital charges, or of freight.

* Reprinted from the Bengal Economic Journal for September 1918 by kind permission of the Joint Editors.

One development of water power, dear to the inventor and the patent agent and cordially disliked by every patent office in the world, is tidal power. It is perfectly true that enormous stores of energy are unutilized in the tides, but, apart from their periodic nature, their development would in most cases cost far more than would suffice to provide the equivalent power by other means. Leaving this branch of the subject to the cranks, there are three, and only three, clearly defined cases in which water power can be developed on sound lines.

Basis of water power and conditions of development.

It is necessary here to explain that the power obtainable in any case is proportional to the product of the *weight of water used* and the *height through which it falls* in the pipes leading to the turbine wheels. Thus 1,000 lbs. of water flowing under a head or height of 100 feet generates the same total amount of power as 100 lbs. of water flowing under a head of 1,000 feet or 10,000 lbs. under 10 feet. In each case, the total is 100,000 foot-pounds; it is immaterial whether it flows quickly or slowly, as this simply affects the rate and not the total amount. In any of these cases, if the assumed weight of water passed through the turbines in one minute, the rate at which power would be developed during that minute (or indefinitely, if the flow continued at the same rate) would theoretically be 100,000 foot-pounds per minute or 3*a* H.-P., of which about 85 to 90 per cent. would be available as mechanical power and 75 to 85 per cent. as electrical power. It will therefore be seen that in order to get power on a large scale it is necessary to find—

(*a*) a small flow of water available with a very large head, which may be anything up to about 3,000 feet, such as may be found in mountainous districts and hill streams at high altitudes.

(*b*) a very large flow of water with a comparatively small head, such as may be found on a canal fall or in a river with a moderate bed slope or a waterfall. (A combination of a large or moderate flow as in (*b*) with a high or moderate head as in (*a*) is an ideal combination but is not a distinct case) ; or

(*c*) a high head coupled with very large monsoon rainfall and ground capable of storing it in large reservoirs. (In this case there may be practically no normal flow; the water

stored in the short rainy season is utilized throughout the year, as in the Tata schemes in Bombay).

It may be stated definitely that the slow-moving rivers of the plains of India, with a fall of a few inches or a few feet per mile, are absolutely valueless as sources of water power. Although in small streams of this nature undershot waterwheels are often used to drive small mills, the problem becomes impracticable on a large scale, and may be relegated to the category of tidal power and the like. A definite fall (whether a natural fall or one developed by the engineer) is essential, and where the slope of the ground is negligible and the seasonal rise and fall of the water is great no practicable fall can be obtained. The common misconception that a natural waterfall is required is of course unfounded.

Steam *vs.* water; capital charges *vs.* fuel.

In all these cases it is obvious that large capital expenditure is necessary on the hydraulic development: furthermore, as water power must be developed where it is found, a long transmission line is often necessary. For these reasons, the total cost of construction is almost invariably higher than that of a steam-driven plant of the same capacity; and the annual capital charges for interest and depreciation are correspondingly higher.

Against this may be set the fact that the running costs of such a station are relatively low, as no fuel is involved. The total cost of running does not depend to any appreciable extent on whether the plant is fully or only lightly loaded; it is practically a fixed sum per annum; so that the cost *per unit* is practically proportional to the total number of units generated. This is not so with fuel-consuming stations. Every extra unit generated then involves the consumption of a definite amount of fuel with a definite cost; and while the total cost rises with the number of units generated and the cost per unit falls somewhat, the latter is by no means proportional to the total units. In any particular case, therefore, the practicability of a hydro-electric scheme depends on the cost of fuel in the locality where the power is wanted.

To take an example, assume a plant of 5,000 kilowatts capacity is required at a certain place where sufficient water power exists within transmission distance. Assume the total cost of the hydro-electric scheme and transmission line to be Rs. 50,00,000. (It might be very much less in favourable circumstances.) Taking

interest and depreciation together at 10 per cent., the annual cost on this account will be Rs. 5,00,000.

Let the cost of a steam plant of the same capacity, built where the power is actually needed, be assumed to be Rs. 15.00.000 with similar annual capital charges of Rs. 1,50,000. Now if for simplicity it be assumed that the annual charges for wages, stores, repairs and supervision are the same in both cases (an assumption near enough to the truth) there will be the difference between Rs. 5,00,000 and Rs. 1,50.000 or Rs. 3.50,000 to set off against the cost of fuel for steam raising. Under the ideal conditions of large electrochemical works this plant, allowing 1,000 kilowatts to be kept for spare and therefore 4,000 for work, would generate about 28 million units (80 per cent. load factor). Under ordinary industrial conditions the output would be less than half this, or say about 12 million units. Clearly, therefore, not only the cost of coal but also the load factor of the plant (*i.e.*, in non-technical language the ratio of its actual to its possible output) is of immense importance. If it is assumed that the low amount of only 2 lbs. of Indian coal will be required per unit, with modern plant of large size, the consumption would be 25.000 tons for 28 millions and 10.700 tons for 12 million units. As the amount available to make the costs just balance out between steam and water power is Rs. 3,50,000, it follows that with the larger output coal at Rs. 14 per ton would absorb this amount, while with the smaller output the figure would be nearly Rs. 33. From this example (in which the figures are not meant to represent estimates) it will be inferred that as the load factor rises towards the ideal limit the advantage of hydro-electric power increases. Bearing in mind the vast difference in the cost of fuel in different parts of India, due mainly to railway freight, it will also be seen that the distance from fuel supplies is a very material factor. With coal under Rs. 10 per ton it is doubtful if water power could ever compete unless (rare combination) it existed right on the spot and could be developed exceptionally cheaply. On the other hand, with fuel at over Rs. 30 a ton, water power would generally prove cheaper and, for a well-sustained industrial load, invariably so. Between these limits proper estimating would be necessary.

An interesting side light on the above discussion is also worthy of mention. The inexperienced financier is notoriously apt to look at present capital expenditure and neglect to take into consi-

deration future recurring costs; consequently he often accepts the lowest tender to his ultimate detriment. We have assumed above that a steam plant of 5,000 kilowatts total capacity cost Rs. 15,00,000, and requires 2 lbs. of coal per unit. Now on the two total outputs assumed the consumption of coal on this basis is 25,000 and 10,700 tons. Would it pay to accept a tender of Rs. 12,00,000 for cheaper plant of the same output if the fuel consumption were then 2½ instead of 2 lbs? The extra fuel used would amount to 6,250 and 2,675 tons in the two cases. Now taking 10 per cent. on the capital cost saved by accepting the lower tender, the annual saving is Rs. 30,000; the extra fuel used, even at Rs. 10 per ton, comes to about Rs. 62,000 with the large output of units and to about Rs. 27,000 with the lower output. Thus with very cheap fuel and a "bad load" it sometimes pays to buy comparatively uneconomical plant; but with expensive fuel and a good load factor *never*. If the cost of fuel assumed were Rs. 15 instead of Rs. 10 the more expensive plant would prove the cheapest on either the large or the small load. Much money has been wasted in India, and much disappointment caused, by the neglect of these principles.

Present developments in India.

At the present time, compared with other countries blessed with plentiful water power, India has made very little use of her resources. Switzerland, Norway and the United States realized the value of this potential wealth long ago, and the war has caused the whole question to be reviewed in order still further to utilise it. There is one actual undertaking of moderate size at work in Bombay Presidency, *viz.*, the Tata Hydro-Electric Power Supply Co. But it must not be forgotten that at the present day there are single generating units of 30,000 kilowatts at work, while the whole of this scheme only amounts at present to 50,000 kilowatts. It is therefore not a very large undertaking, except by comparison with others in India. Two other similar undertakings are projected in Bombay. Over the rest of India there are only two or three fair sized hydro-electric plants and a few small ones for domestic supply. Of the former, that on the Cauvery is the most important, as its output is mainly used for industrial purposes on the Mysore gold fields.

The chief industrial uses of electricity.

Hitherto, in the public mind, electricity has been mainly associated with lighting and fans. These are excellent in their way, and it is grievous to see how little they have been developed in the

last 20 years. In the industrial life of a country, however, they can play but a small part, subsidiary to manufacturing industries. Slowly but surely the driving of mills and factories by electricity is coming into play, and there is yet a great extension possible of electric driving. But it is in the use of electricity directly, in the furnace, the arc or the electrolytic cell, that the real future lies. The most important processes are perhaps those for the fixation of atmospheric nitrogen into the nitrates of commerce. Norway was the first country to develop this industry on commercial lines, and now, when nitrates are scarce and freights heavy, and the peaceful demands of agriculture have been superseded by those of war, other countries are hastily making up leeway. The production of aluminium from alumina, of which bauxite is the most generally used raw material, is perhaps next in importance to the nitrates. The steel industry, again, is being slowly revolutionized by the electric furnace, which introduces economies in the utilization of what has hitherto been regarded as scrap and turns out a finished product superior to that of other and older methods. Amongst other processes of importance are the electrolytic production of the carbides of calcium (for acetylene), etc., and of chlorine (for bleaching and poison gas); the manufacture of phosphorus; the electrolytic preparation of various rare metals of use alone or as alloys; and the synthesis of carborundum and other abrasives in the electric furnace.

Power factor and cheap units for industrial power.

In most water-power plants hitherto developed the capital cost has been high, and the sale price per unit correspondingly so. If the technical discussion above has been mastered, it will be evident that, as the total annual cost is practically a fixed sum, the unit can be sold far cheaper to a consumer who is using all his machinery, etc., throughout the 24 hours than to one who only uses it for 2 hours; in fact, in the ratio of about 12 to 1. This is the reason why consumers always have to pay higher rates for domestic lighting than for industrial power; it is true whatever the source of power may be, but more so with water power than with steam. The usual selling rates for lighting in India are from 3 to 6 annas a unit; for industrial power from 1 to 2 annas where steam is used and somewhat less where the plant is water operated. Here again an interesting contrast may be drawn between steam and water. No matter how ideal the

conditions may be, every unit sold from a steam station costs a definite sum in fuel; and therefore, even though some of the plant may be idle, there is an absolute limit below which sales would result in loss. Paradoxical though it may seem in view of all other commercial transactions, there is practically no such limit in the case of a hydro-electric station. The total working costs are not affected by the generation and sale of additional units. Therefore, when all the load has been obtained that is in sight, at normal tariff rates—for dividends must be obtained—extra sales at any price will pay so long as they do not involve an increase in the size of the plant. They bring in money without involving any expenditure. This will be more evident if an example, simplified in order to avoid diagrams, is given. Suppose a hydro-electric plant with a working capacity of 4,000 kilowatts actually had this load (or thereabouts) during the whole working day from 6 A.M. till 6 P.M., but that for the remaining 12 hours its average load was only 1,000 kilowatts, the average generating cost of a unit being 0·5 anna under these conditions. If there was no prospect of obtaining work for the idle plant during these night hours on the ordinary tariffs, it would pay to take on consumers at 0·3 or 0·2 or even 0·1 anna per unit *provided* they were restricted to the use of power at night only. Of course their additional consumption would bring down the average cost of a unit. If, for instance, night working factories were started, using the whole available 3,000 kilowatts, the average cost would be reduced from 0·5 to about 0·3 anna. But, as stated, in order to get this extra revenue it would pay to supply this factory at a far lower figure than the reduced average. It is, in fact, constantly done in actual commercial undertakings.

Conditions for economical industrial development.

Where electro-chemical industries on a large scale are in question it is essential that the price of the power shall be very low, if the manufactured product is to compete with that produced elsewhere. The cost of power is of course only one item amongst many in determining the sale price of the finished article, but it is a very important item—perhaps second only to the freight of the raw material to site and the finished product to market. Where the conditions of the hydraulic development are such that construction on a large scale is reasonably cheap; where the locality is such that the freight of the plant and materials thereto is low;

and where the length of transmission to the factory is reasonable; power can probably be delivered at about one-tenth of an anna per unit including all charges. Indeed, if the cost is much higher than this, the proposition becomes untenable. Obviously, the undertaking must be on a fairly large scale to be of any use. The larger the individual units of plant are made the smaller becomes their prime cost per kilowatt and the higher their efficiency. The various electro-chemical industries are favourable to these low costs as they are practically continuous processes, utilizing the whole plant to almost its utmost capacity throughout the year.

Freight.

In considering the value of sites that may possibly meet these ideal conditions, the first point to consider is undoubtedly that of freight and carriage; for it has a triple application. In the first place, the raw material must be brought to the site, unless already on it; secondly, the finished product must be taken to its market: thirdly, the plant must be delivered at the power house. Cases are known where the carriage of plant over 20 miles of mountain roads cost more than its freight from England to the railway terminus. Cheap power is useless if the saving is swallowed up in expensive freight. Where bulky raw material has to be brought to the factory and sent back finished, the obvious course is to build an electric railway from the nearest terminus, seeing that cheap power for working will be available. In order to get the plant to the power house there must be a road, and this road should be built so as to afford a suitable track for the subsequent railway. During the construction period, a light line worked by steam will probably pay as against other methods of transport of the plant. The tendency of the man who put his travelling crane up after erecting his plant is often only too apparent in these matters, and carriage by coolie is seldom cheap.

Transmission of power.

From small beginnings electrical transmission of power has now reached the stage where it is possible to have the factory 250 miles or more from the power station, and it would be unwise to say that the limit of high pressure has been reached. In the case of water power from mountainous country, there may be insuperable difficulties of ground or cost in laying out a railway to the size, though the plant can be transported there. Even if these difficulties do not exist, if the raw material of the industry

is within the limits of transmission it will probably prove cheaper to erect a long transmission line rather than a railway, which may use more power than will be lost in transmission. It is simply a question of estimating which method gives the cheapest finished product. Either the material can be brought to the power house; or the power to the factory; or a combination of both methods may be the best. Mountainous country has one great asset for transmission in that the ridges form nature's own supports for the lines; with comparatively small towers, the valleys offer plenty of room for the dip of the wires on long spans. It also follows that by reducing the number of points of support, by the use of long spans, there are fewer points at which damage from lightning can occur. The loss in transmission can be made almost as large or as small as the designer chooses, according to the size of the wires used; ordinarily about 10 per cent., is allowed. Where steam is used to generate the power, the correct loss can be calculated according to Kelvin's law and its modifications, such that the capital charges on the conductors balance the cost of the power lost in them. If more power is required, more generating sets can be added indefinitely. With unlimited water power, the cost of the lost power is of secondary importance, and larger losses may be advisable than in the former case. On the other hand, if the available power is likely to be all required—and this is generally the case—the line losses may have to be reduced to very low amounts, since every unit available for the factory is of value.

Cheap development.

In large steam-driven plants, the capital cost of the power house and plant is a matter which can be forecasted with accuracy, except for the cost of freight and carriage, independently of where the site may happen to be. This cost may be more or less within comparatively small limits, especially according to whether there is a satisfactory water supply for the boilers and for condensation: and this latter point will affect the running costs greatly. On the other hand, the capital cost of a hydro-electric scheme may vary enormously in different cases. In the first of the three classes of undertaking enumerated in the early part of this article, namely, large heads of water with a small flow, the water has generally to be carried along an open flume for miles in order to reach a point at which the large available drop can be utilized by means of the shortest length of steel pipes. Then a certain amount of storage at this pipe head is essential,

in order to guard against the failure of the supply through a break in the flume. Then, again, the steel pipes themselves may be longer or shorter according to the ground. Landslips and bad ground have to be guarded against, tunnels constructed, and other streams bridged. These various conditions involve enormous variations in capital cost, which can only be forecasted by surveys and estimates.

The second class of undertaking, with low or moderate falls and a lärge volume of water, includes both canal and river developments. Canal falls are for the most part very small, and though the power house and foundations will generally be expensive the rest of the development does not vary greatly in cost. Annual closures, however, militate largely against the use of these falls for industrial purposes other than sub-soil pumping or high level irrigation. River developments, except that they usually do not require storage reservoirs, may vary indefinitely in cost. Difficult problems are involved in drawing off the water at the headworks and in conveying it to the power station, and the limits of cost may vary almost as much as in the case first considered. Floods and the great variation in the height of the head and tail waters offer further difficulties.

In the third class of undertaking, large storage is the crux of the problem. No matter what the monsoon rainfall may be, unless sound natural reservoir sites exist, development is impossible. If dams can be built to impound enough water to run the station through the year, and if the capital cost does not prove so great that steam would be cheaper, well and good. Here the height of the reservoirs above the power station must be as large as possible, for every extra foot means extra power. On any given head, every ton of water behind the dam represents a certain definite quantity of power in horse-power hours (or in units) and in money; and as the quantity of water is limited every extra foot in height means additional revenue. Thus every hundred rupees spent on masonry may provide an amount of power varying both according to the altitude of the dam above the power house and the number of cubic feet of water it stores, depending on the configuration of the ground.

Basis of hydro-electric survey.

All these problems require expert investigation. The first stage in such an investigation is to decide what industries are to be undertaken, where the raw materials of the same are to be found,

and the power required for them. The next stage, which could be independently examined, is to ascertain the sites where sufficient power is available and capable of development at reasonable cost. It must again be urged that, as the extra large capital involved is merely a set off against fuel, the rent charged for the use of the water in a canal or river should be absolutely nominal: for passing it through turbines does not prevent its subsequent utilization for irrigation. Thirdly, the practicability of bringing the raw materials and power together must be examined, together with questions of freight and carriage. Finally, although in most cases the result is a foregone conclusion, it must be determined whether coal utilized at the pit's mouth can or cannot compete with water power; and in this connection existing railway facilities evidently play a considerable part.

There is work here not only for the electrical engineer but also for the chemist, the geologist, the meteorologist, the irrigation engineer and the water-power expert. Conflicting claims are bound to arise, but the ultimate good of India should be the deciding factor.

Electrical and Mechanical Engineering in India.

BY H. BURKINSHAW,

Controller (Electrical and Mechanical) Indian Munitions Board.

At the outbreak of war India found itself singularly ill-equipped to cope with its own demands for mechanical and electrical machinery and appliances. Large imported stocks were, however, available and these, for some time, served to relieve a situation which might otherwise have been disastrous.

Machine tools.

The reduction in imports of all manufactured goods necessarily increased the pressure upon Indian factories and this, in turn, created a very large demand for machine tools without which it was impossible to manufacture new machinery and spare parts for existing machinery. These machine tools were supplied almost exclusively from imported stocks, but a number of the simpler kinds were manufactured to meet very urgent cases. Hitherto, private enterprise does not appear to have attempted to manufacture machine tools capable of working with that degree of precision and speed demanded by modern methods. That such machinery can be produced in India has been clearly demonstrated. and notable examples are the exceptionally high class lathes manufactured in the Lillooah Workshops of the East Indian Railway. The manufacture of machine tools in India is of the utmost importance as, without them, no other machinery can be produced and all industry must be hampered. It is fortunate, therefore, that the manufacture of machine tools in India is likely to be established in the near future.

Machinery.

Heavy machinery requiring no great degree of precision in manufacture, such as slow speed steam engines, hydraulic presses, pumps, looms for coarse fabrics, mortar mills, colliery haulages, etc., is readily manufactured in India and many such machines are in successful operation.

Several engineering firms have now standardised these machines and their productions are at least equal to those previously imported. It has been possible to comply not only with the normal demands but also with those from the army, and there appears to be no reason why the import of this class of machinery should again rise to its pre-war value.

Portable engines, traction engines and road rollers are not manufactured in India. Small vertical, and Lancashire type boilers have been made in rare cases, but the total output is small enough to be practically negligible. This type of machinery is required in large quantities, and India is dependent entirely upon imports.

Before the war, engineering firms in India principally concerned themselves with the non-recurring demands for machinery not usually imported, mill-wrighting, repair work and steel structural work. They have since had to turn their attention to the manufacture of a diversity of machines and parts of machines for which their workshops were imperfectly equipped. The results obtained reflect great credit upon the perseverance and ingenuity of individuals, and it has generally been possible to obtain from them anything which was of vital urgency. But in the present state of industrial development in this country, these efforts must be regarded for the most part as *tours de force* and, when peace conditions return, for a time at any rate, India must expect to a great extent to fall back to her pre-war dependence on imported machinery. The reason of this is obvious. Modern engineering works use largely certain products which they do not themselves manufacture. Amongst these are, pig iron, mild steel tubes, wire, plates and sections, copper and brass rods, tubes, bright-machined screws and nuts, wood screws, split pins, washers, tool steel, twist drills, cutters, springs, etc., etc. With the exception of pig iron and mild steel sections, engineers in India are dependent for all these almost entirely upon imports, and until these conditions are altered the manufacture of machinery to meet the very large demands cannot well be undertaken.

Electrical machinery and appliances.

The manufacture of electrical machinery, such as dynamos, motors, transformers, etc., has not been attempted in India on account of the difficulty of obtaining the requisite material. The principal materials required are cast iron of high permeability, mild steel, thin iron plates with special magnetic properties, copper wire, copper bars of special sections, cotton yarn and tape, mica, press-

spahn and certain varnishes, in which shellac is usually an ingredient. After experiment, it would doubtless be possible to produce suitable cast iron, but there is no immediate prospect of producing from indigenous sources the thin iron core-plates, electrolytic copper wire and sections, cotton yarn and tape, and press-spahn. The cotton tape and yarn required must be made from fine counts, entailing the use of long-staple cotton, and the finished product must be entirely free from dressing and of uniform dimensions. This has not yet been produced in India.

A certain amount of switch gear for direct current has been manufactured in India during the war, and the results reflect great credit upon the firms concerned, the gear comparing very favourably with similar imported articles. The difficulties of manufacture have been great, as with the exception of pig iron for the castings, recourse has had to be made to imported copper sheets, brass bars, etc.; and in almost every case it has been necessary to utilise such material as was obtainable, rather than that which would normally have been used. All small pins, screws, nuts, springs and washers have had to be manufactured, either by hand or upon unsuitable machinery, and this has resulted in increased cost of production and the sacrifice of interchangeability.

A notable achievement has been the successful production of electrical porcelain, the insulators now produced in India being in every way equal in quality to the usual imported types. None were made in India before the war and, if the existing factory is extended to supply insulators in large quantities, there appears to be no reason why the import of this article should not cease. If electrical porcelain becomes readily available, factories could be established for the manufacture of such accessories as ceiling roses, tumbler switches, wall plugs, cut-outs, distribution fuses, etc., etc., all of which are at present imported.

All such electrical fittings as water-tight lanterns, deck fittings, ironclad plugs and sockets, hand lamps, table lamps, plain glass globes, and the like are now manufactured in sufficient quantities to meet the present curtailed demand. In many cases they are superior to the imported article and only in rare instances is there a marked inferiority.

No attempt has been made to produce insulated conductors and insulating materials (except porcelain), and the whole of the requirements have been met from imported stocks. The rubber now

produced in Southern India, however, is of very high grade and eminently suitable for electrical purposes, and there is no insurmountable obstacle to be overcome for the production in India of all types of insulating materials and insulated conductors.

Materials.

Although manufacturing firms have at present to depend so largely on imported materials for their work, practically all the raw materials required for mechanical and electrical engineering manufactures are indigenous to India, and there is no reason why these resources should not be developed. Mills for the production of steel, copper and brass plates, rods, tubes and wire, are urgently required, and also the establishment of works for the production in bulk of machined bolts and nuts, screws, gudgeon pins, washers, split pins, etc., etc. It will be seen from the other articles in this handbook that there are excellent prospects of many of these products being manufactured in India in the near future and should these materialise, the manufacture of practically all types of machinery and electrical appliances could be undertaken with a certainty of success.

Labour.

There remains the labour factor, and it is satisfactory to note that the results obtained in the State workshops (which have not been mentioned in this note as their resources are not usually directly accessible to the public), and in up-to-date privately-owned shops demonstrate that the Indian workman can produce work of a markedly high quality, when he is given proper facilities. It is true that expert labour is not equal to the demand and this will no doubt at first hamper the expansion of the engineering industries. But the capacity is there, and the lessons which the Indian will learn from the imported skilled artisan and the training and education which he will receive, if the recommendations of the Industrial Commission are carried out, should result in time in the provision of an ample indigenous labour force.

To sum up, the engineering manufacturing resources of India are not yet sufficiently developed to compete with imported machinery, but the possibilities for development are enormous, most of the raw material is available, the labour can either be procured or trained, and the market for the products is assured. It remains for private enterprise to avail itself of its opportunity.

Hides, Tanning, and Leather.*

BY A. C. MCWATTERS, C.I.E., I.C.S.,
Controller (Hides).

The war has brought about important changes in the Indian tanning industry and in the export trade in hides and skins; naturally, through the cutting off of enemy markets, and artificially, through the control exercised by Government. The latter has been directed towards increasing the outturn and regulating the production of those kinds of leather which possess a special value as war material.

East India tanned kips: increase in production.

The most important development has undoubtedly been the great increase in the production of rough-tanned cow hides, known as East India tanned kips, from the Madras and Bombay tanneries. The export to the United Kingdom of East India kips has been an important trade for a number of years, but it was not until the war had been in progress for nearly a year that their value as upper leather for army boots was fully realised in England. Once this was realised, however, every effort was made to increase and regulate the supply. From August 1916, the Indian Government, at the request of the War Office, assumed complete control of the trade and has purchased in India the whole of the available supply, for export direct to the War Office. On the creation of the Indian Munitions Board, the control of the arrangements for purchase of East India kips was taken over by the Board.

At least three-fifths of the upper leather used in the United Kingdom in the manufacture of boots for the British and Allied armies is supplied from East India kips. The magnitude of the trade may be realised from the fact that the requirements of army upper leather for the year 1917 were estimated at eighty million

* A bulletin on this subject is under preparation.

feet, as a minimum. East India kips give an average of 24 feet when dressed into "sides", but less when dressed into "butts." Taking an all-round figure of 18 feet, 1,500,000 kips, which was the average annual production suitable for upper leather in the years preceding the war, would give 27,000,000 feet of upper leather. The present output is more than double this quantity.

The actual figures of exports, given below, show the remarkable increase in this trade since the war. The figures include a small proportion of tanned buffalo hides and calf, which are also included in the Government purchase scheme, but by far the greater part consists of tanned cow-hides.

TABLE 1.—*Exports of tanned hides from India from 1913 to 1918.*

Year.	Quantity shipped.	Value.
	cwts.	Rs.
Pre-war years—		
1913	194,763	*1,75,10,805*
1914	187,702	*1,98,41,370*
War years—		
1st April 1914 to 31st March 1915	217,020	*2,40,99,740*
1st April 1915 to 31st March 1916	272,002	*3,06,23,737*
1st April 1916 to 31st March 1917	322,390	*4,42,12,337*
1st April 1917 to 31st March 1918	361,674	*4,86,98,822*

The figures given above for the year 1917-18 do not adequately represent the increase in outturn during the year, as on the 31st March 1918 Government held in stock at Madras awaiting shipment 12,400 bales weighing approximately 67,000 cwts. and valued approximately at one crore of rupees. The increase both in quantity and value can be appreciated better if the above figures are represented by index numbers, 1913 being taken as the standard and represented by the number 100.

TABLE 2.—*Index numbers of exports of tanned hides.*

Year.	Quantity shipped.	Value.
1913	100	*100*
1914	96	*113*
1914-15	111	*138*
1915-16	139	*177*
1916-17	165	*255*
1917-18	186	*278*

The prices paid for East India kips are thus seen to have increased more rapidly even than the quantity.

Increase in army selection hides.

The action taken by Government has not been confined to increasing the production of tanned kips. Various steps have been taken with the object of increasing the proportion of army selection leather and reducing the proportion of light weights and rejections, which, although they command a high price in the civil trade at Home, are unsuitable for army work. In the first place, the scale of prices framed by Government is much more favourable for army selections than for non-army selections and when the prices at Madras were revised in May 1917, this policy was carried still further, with the result that much greater profits can be obtained by tanners who purchase the best selections of hides than by those who tan all-round average lots. In Madras, army selections are classed as seconds, thirds and superior fourths in weights from 6 to 18 lbs. and 18 to 25 lbs. Light weights below 6 lbs., inferior fourths, fifths and rejections comprise non-army selections. The present price basis f. o. b. is from Re. 1-6-9 per lb. to Re. 1-3-3 for the ordinary run of parcels containing a fixed proportion of seconds, thirds and superior fourths. The price of fifths varies from Re. 0-13-6 to Re. 0-10-9, and for rejections 9 annas per lb. is paid. At Bombay, an all-round tannery price for army selections of Re.1-4-0 per lb. is paid, while rejections are classed as "superior" at Re. 1-0-0 per lb. and "inferior" at Re. 0-12-0 per lb.

Prevention of adulteration.

In the second place, steps have been taken to prevent adulteration and improper weighting of hides. In the early days of the Government scheme it was found that adulteration of hides by the addition in course of tannage of magnesium salts, sugar and other

adulterants was on the increase. The leather adulterated in this way was liable to be completely spoilt, or at the best considerable expense was incurred by the adulterants having to be washed out in England. Attempts were made to check this practice by penalising heavily all adulterated hides presented to Government and by refusing altogether badly adulterated hides. But adulteration is not in all cases easily detected without chemical analysis, and eventually, with the full approval of the commercial community in Madras, the practice of adulterating hides was made a penal offence by an order passed under the Defence of India Rules. In addition, however, to this form of adulteration, it used to be a prevailing practice in the case of certain tannages to add weight to the hide by the application after tannage of chalk and plaster to the flesh side. This, although not injurious to the leather in the same way as adulteration, adds nothing to the value of the leather but is merely a form of artificial weighting. The chalk and plaster has in all cases to be washed off by the currier in England before the hides can be used. This practice also has recently been prohibited by an order under the Defence of India Rules. The result has been that several of the so-called distinctive tannages in Madras have become practically indistinguishable from one another and instead of recognizing eight or nine separate tannages, it has now been possible to classify all Madras tannages into four main grades—primes, best, good and ordinary, each of the first three being sub-divided into two classes according to their growth and spread. There is no doubt that this simplification of classification and the prohibition of artificial weighting of hides will be much appreciated by the home curriers, and it is to be hoped that the improvements effected in this direction, as a war measure, may not be entirely lost in times of peace, as they will undoubtedly enhance the reputation of East India kips in the home markets.

Faulty flaying of hides and branding of cattle.

In the third place, the Indian Munitions Board has called the attention of Local Governments and their officers and of the public to the loss of valuable leather which is caused in India by the faulty flaying of hides and by the branding of cattle. The Provincial Controllers of Munitions have also been asked to interest themselves in the matter. A pamphlet prepared in popular language by the Director of Industries, Bengal, on the proper method of flaying and

curing hides has been widely circulated through all provinces and is being translated into different vernaculars. Though not much general progress can at present be reported, the improvement effected at the Bandra slaughter-house in Bombay, where control is exercised directly through the Deputy Controller for Hides, Bombay, is an example of what can be done by proper management. By obtaining more time for the butchers to do their work properly and by paying a small premium for all well-flayed hides, the proportion of hides from this slaughter-house rendered unsuitable for army work by faulty flaying has been reduced from about 60 per cent. to less than 5 per cent. Good results are also reported from Rangoon where a similar system has been introduced.

The result of these various measures has already been to increase the proportion of tanned kips suitable for army work, which is now about 65 to 70 per cent. of the whole. Further improvement can, however, still be made. In the tannery directly worked by Government at Bombay, for instance, during the first year's working the proportion of army selection hides produced has exceeded 90 per cent. This result was obtained not merely by the careful purchase of suitable hides, but by the constant supervision exercised at every stage of the processes of liming and tanning.

Tanning bark.

The tanning of East India kips has practically been confined to the areas in which the bark of *Cassia auriculata*, known in Madras as *avaram* and in Bombay as *tarwad* is obtainable. These areas comprise the Madras and Bombay Presidencies, and the Mysore and Hyderabad States. Outside these areas, the cost of railway freight makes tanning with *tarwad* commercially unprofitable. There is, moreover, not more than a sufficient supply of the bark for the tanneries in the areas named and prices for bark have risen far above pre-war levels, though they are now controlled by Government action. The future of the trade in East India kips undoubtedly depends on the continuance of sufficient supplies of *tarwad* bark at cheap prices. The cost of tanning has more than doubled since the war, mainly because of the increased cost of bark and other tanning materials, but, when peace conditions are re-established, East India tanned kips will depend for their market in the United Kingdom on their cheapness as compared with other leathers with which they will have to compete. For this reason the Munitions Board has urged Local Governments to take measures at once to increase and systematise

the cultivation of *tarwad* in all suitable areas, and this question is being actively taken up by Local Governments both in forest areas and other lands.

The Government Tannin Research Factory.

In the second place, attention was devoted by the Munitions Board to the discovery and proof on a commercial scale of substitutes for *tarwad*. The great merits of *tarwad* bark are that it is very easy to use and quick in its action; it adds weight and plumpness to the hides and produces a leather which is capable, after further treatment by the currier, of being turned to a variety of uses. No other tanning material has yet been discovered which has all these qualities, but promising results have already been obtained from a variety of mixtures of Northern and Central Indian tan-stuffs, which hold out prospects of a great extension of tanning in Northern and Central India. The Munitions Board acquired the factory belonging to the Esociet Company of Maihar in Central India, where experiments with these new tan-stuffs have been conducted for some years, as a Government Tannin Research Factory, and purchased the Allahabad Tannery with a view to proving these new tan-stuffs on a commercial scale. A note by the Director of the Government Tannin Research Factory, which shows the work done and in progress at the Factory, will be found elsewhere (see page 171).

Tanned skins.

The tanning of sheep and goat skins with *tarwad* bark is also a large industry in the same areas where East India kips are tanned. During the first two and a half years of the war, the tanners of skins were exceptionally prosperous and prices of tanned skins in England, the United States of America and Japan ruled high. In 1916-17, prices rose to a phenomenal level, as will be seen from the following figures :—

TABLE 3.—*Exports of tanned skins from India from 1914 to 1917.*

Year.	Quantity exported.	Value.
	cwts.	Rs.
1st April 1914 to 31st March 1915	117,405	2,32,34,055
1st April 1915 to 31st March 1916 . . .	127,322	3,54,87,669
1st April 1916 to 31st March 1917	162,919	4,84,85,843

These figures may be represented by index numbers with 1914-15 as a basis :—

TABLE 4.—*Index numbers of exports of tanned skins.*

Year.	Quantity.	Value.
1914-15	100	*100*
1915-16	109	*109*
1916-17	139	*208*

Tanned skins have not an extensive use for war purposes and it was found that the high prices obtainable were leading to the tanning of skins at the expense of East India kips, and the competition for tanning bark between skin and hide tanners was resulting in unsatisfactory supplies and extravagant prices for bark. The supply of East India kips for the War Office was seriously endangered, and Government was compelled to take the step of prohibiting any further tannage of sheep and goat skins in the Madras and Bombay Presidencies from the 28th April 1917, and of prohibiting all export of tanned skins from India after the 15th May 1917. Permission was subsequently given to export the balance of stocks of tanned skins held on 31st August 1918. In 1917-18, only 37,318 cwts. of tanned skins were exported, but these were valued at the very high figure of Rs. 1,47,40,068.

Every effort was made to induce the tanners of skins to turn their attention to tanning hides and many of them assisted Government by so doing. The shipping firms in Madras also loyally co-operated in endeavouring to carry out Government's policy in the matter, which was recognized to be necessary as an emergency measure under present war conditions. It is expected that the tanned skins trade, which has suffered a temporary set-back owing to shortage of tan-stuff, will recover rapidly on the conclusion of peace.

Supplies of accoutrements and army boots.

In addition to the export trade in East India kips, Indian tanneries have produced during the war greatly increased quantities of leather accoutrements of all sorts and boots for the army in India and the Indian Expeditionary Forces. These supplies also were

controlled by the Munitions Board. The stimulus which these large Government orders have given to the tanning industry may be measured by the fact that two million pairs of boots are now being manufactured in a year, or more than 20 times the pre-war figure. In addition, orders have been placed for nearly a million followers' shoes during the current year, thus bringing work to a large number of shoemakers. The monthly output of the Government Harness Factory at Cawnpore has increased from 33,000 lbs. of leather in 1913-14 to nearly 200,000 lbs. during the first three months of 1918-19. During 1916-17, the latest period for which detailed accounts are forthcoming, the total value of the outturn of the Factory was Rs. 52¼ lakhs. The Superintendent of the Factory also controls several large tanneries at Cawnpore, which, as a result of the instruction given, are turning out leather of first-class quality. Large orders for saddlery and equipment have also been placed with outside firms which, it is expected, will result in a great improvement in the standard of leather making in India. There has been an important development also of tanning in Calcutta. The Munitions Board has in addition arranged to supply some 35,000 East India kips monthly for Cawnpore factories engaged in boot manufacture and 8,000 monthly for the Government Harness and Saddlery Factory from the tanneries in Bombay.

The war has not provided any great opportunity for developing chrome tanning, since not only is the machinery difficult to obtain in war time, but the demand for war purposes at Home has been entirely for East India kips, and chrome leather from India has not hitherto been accepted by the War Office. It is probable, however, that after the war there will be greatly increased opportunities for this class of tanning, especially in the production of glacé kid from Indian goat skins. It may be added here that Government has secured from England the services of an expert tanner to assist them in the development of the tanning industry.

Roller skins, picker bands, etc.

The Munitions Board has endeavoured further to stimulate the manufacture in India of certain classes of leather goods previously imported from abroad. Early in June 1917, the Board called the attention of firms in India to the possible market for locally manufactured roller skins, picker bands, leather belting and raw hide pickers. Applications from firms desirous of importing these articles were being received in large numbers. The Board accordingly informed

Indian firms that, if they could satisfy it by production of suitable samples that these articles could be satisfactorily made in India, priority applications for import from abroad would be refused and applicants would be referred to the firms in India who had shown themselves to be capable of producing the articles.

Encouraging results have already been obtained in the case of roller skins and picker bands, in the manufacture of which at least eight firms in India are now engaged. In the supply of roller skins to Indian cotton mills local manufacturers have made great progress, and the estimated outturn is about 1,200 dozen skins per week. This is actually in excess of the demands of the mills, many of which continue to use imported skins, and a number of roller skins have been exported from India to foreign countries, especially Japan. The chief advances have been in the production of chrome leather belting, which has been largely purchased for Government purposes, and the making of jute pickers which are used by a number of mills. Neither of these articles is yet as satisfactory as its imported rival, but a good standard has already been reached and as the manufacturers have still some time to profit by their previous experience before they will be exposed to free competition, there is ground for confidence that the manufacture of these articles will be successfully established in India.

Another line in which successful experiments have been made is the supply of sheep skins for polishing rice in Burma.

Before concluding the subject of hides and tanning, a short reference may be made to the export trade in raw hides. Indian raw hides in the year immediately preceding the war went mainly to Germany and Austria, but with the closing of these markets the trade has found openings in Italy, the United States of America and latterly in England, where endeavours are being made to extend the capacity of English tanneries, so as to deal with larger supplies of Indian raw hides. Since June 1917, the control of exports of raw hides for English tanners working on War Office orders and for the Italian Government has been in the hands of the Munitions Board. The difficulty of securing freight and finance for other than Government purchases and still more the great increase of tanning in India of hides—both cow and buffalo—for war requirements, have led to a considerable reduction in raw hide exports. The quantity of raw hides exported in the year 1917-18 was only slightly more than

Raw hides.

the quantity of tanned hides shipped from India, and was considerably less in value.

The following figures show the volume, direction and value of exports of raw hides :—

TABLE 5.—*Exports of raw hides from India from 1913-1918.*

—	Quantity shipped (in cwts).	Value (Rs.)	Average price per cwt.
Pre-war years—			Rs.
1913	1,132,348	*7,99,44,840*	70·6
Germany	408,737	*3,02,33,150*	
Austria	211,213	*1,19,77,155*	
United States of America	147,957	*1,00,46,190*	
Italy	107,494	*61,17,115*	
United Kingdom	52,507	*70,28,395*	
1914	897,785	*7,17,40,185*	79·9
Germany	282,310	*2,43,66,915*	
United States of America	176,945	*1,29,60,100*	
Austria	160,724	*1,43,03,895*	
Italy	82,926	*69,20,160*	
United Kingdom	68,268	*46,79,955*	
War years—			
1914-15	713,926	*5,25,10,395*	73·5
United States of America	189,173	*1,26,93,525*	
Germany	146,575	*1,24,92,975*	
United Kingdom	132,322	*85,61,995*	
Italy	72,109	*57,63,135*	
Austria	60,143	*49,74,260*	
1915-16	881,885	*6,78,63,843*	76·9
Italy	383,300	*3,29,18,700*	
United States of America	312,905	*2,25,69,225*	
United Kingdom	99,290	*65,13,825*	
1916-17	894,028	*7,40,20,126*	81·6
United States of America	461,107	*3,85,75,770*	
Italy	172,871	*1,61,23,570*	
United Kingdom	145,140	*1,19,20,935*	
1917-18	417,903	*3,08,66,376*	73·8
United Kingdom	176,847	*1,28,53,290*	
Italy	156,231	*1,16,62,150*	
United States of America	78,123	*68,57,935*	

Raw Skins.

The export of raw skins, principally to the United States of America, is also a large trade, and showed a marked increase in quantity and a still more marked increase in value in 1916-17. This increase was not fully maintained in 1917-18, mainly on account of difficulty in finding freight to America and on account of market conditions there being less favourable than in the preceding year.

The following are the export figures :—

TABLE 6.—*Exports of raw skins from India from 1913-1918.*

Year.	Quantity (in cwts.)	Value (Rs.)	Average value per cwt.
Pre-war years—			Rs.
1913	503,680	*3,40,00,410*	67
1914	442,649	*2,88,91,570*	65
War years—			
1914-15	408,448	*2,54,33,743*	62
1915-16	432,667	*2,99,27,770*	69
1916-17	567,046	*6,90,51,241*	122
1917-18	429,028	*4,74,55,739*	111

Note on the progress of Researches to apply the Natural Tanstuffs of Northern India to the production of War Leathers.

BY W. A. FRAYMOUTH, F.C.S.,
Director, Esociet Tannin Research Factory, Maihar, Central India.

Since the Esociet Company's research work was taken over by the Indian Munitions Board, when the Tannin Expert to Government was posted to collaborate with the Director of the Research Factory, in March 1917, a large number of unknown, or little known, tanstuffs, common in the jungles of Northern India, have been examined, both alone and in combination, in the laboratory and by practical tanning tests, and finally the best results have been applied in a small tannery (50 hides per day), where working costs and financial results have been studied. The results obtained up to March 1918 have lately been published in the Director's First Annual Report and the Bulletin No. 1: "Indian Tanstuffs and Their Tannage" by W. A. Fraymouth, F.C.S., and J. A. Pilgrim, L.T.C., copies of which are obtainable from the Secretary, Indian Munitions Board.

It will be of interest to relate the progressive experiments which have led to the results so far obtained.

Tarwad.

The exceptional tanstuff *tarwad* had long been used in the south of India, Madras and Bombay, to turn an Indian kip (*i.e.*, a small cow hide) and both goat and sheep skins, into a special form of leather, lightly-tanned, with an elastic grain, of a pale colour and with great tensile strength. These leathers were produced in small hand-tanneries in Madras and Bombay, to be exported to the tanneries in Europe and America, where they were finished, sometimes by loading with more tannin and oils, sometimes by simply filling the leather with oils and fats, and mostly by splitting to an even thickness, re-tanning and finishing with dyes, glazes, etc. This so-called "half-

tan," or more properly *tarwad* leather, after treatment by the currier, produces a very suitable leather for the uppers of army boots, and has been extensively so used during the war.

The supplies of *tarwad* bark were always insufficient to keep up the quantity of this leather required for war purposes. It is, however, not to be disguised that wherever and whenever this tanstuff, *tarwad* bark, can be delivered into tannery at under Rs. 2 per maund, it will always afford an almost perfect agent to re-produce half-tan leather. But there are many places in India where those conditions can never exist.

Tarwad substitutes.

The first direction of the experiments undertaken at the Research Factory was to find other tanstuffs to eke out the available supplies of *tarwad* by dilution. It was established at an early stage that *dhawa* Sumac (*Anogeissus latifolia*), a powdered leaf-tanstuff, carrying 30 per cent. tannin, with a distinctive bleaching property, can be used in mixture with *tarwad* up to one-third of the whole with success, and further that if the partly exhausted *tarwad* bark as thrown away from the tanneries of the south (containing 8 per cent. tannin), be crushed and mixed with *dhawa* Sumac in equal proportions, a leather like *tarwad* leather can be produced. *Dhawa* bark also was used as well as other diluents, *gothar*, *aonla*, etc. When Mr. Pilgrim visited Madras in September 1917, he described the collection of *dhawa* Sumac and its use in mixture with *tarwad* bark and further research on these lines has been carried out at the Madras Leather School. These experiments gave promising results, but large-scale trials which have been made by a number of Madras tanners have so far proved somewhat disappointing, as the leather has been found to lose both in colour and weight.

Endeavour was then made to find a tanstuff or a combination of tanstuffs that would produce exactly the same kind of leather as *tarwad* leather. The Research Factory has always been guided by certain principles. These are :—

(*a*) to take those tanstuffs, which can be got annually without the destruction of the tree, unless the bark happens to be a waste product from timber getting and to look for those tanstuffs which come from widely-distributed species ;

(*b*) to develop those tanstuffs which concentrate easily by jungle methods to a product that will pack closely,

containing the maximum amount of tannin, and so to offer to the tanner a "cheap unit of tannin";

(*c*) by tanning tests to prove that the tan-stuffs will produce good and cheap leather alone or with other tan-tuffs, and finally to prove the results on the practical hand-tannery scale.

The first combination that yielded leathers which met with the approval of the War Office representative was a quarter each of the *dhawa* Sumac, *dhawa* twig bark, *aonla* twig bark, and *mahurain*. This mixture and modifications thereof have been in use at the Government Tannery, Allahabad, the leathers from which are now being used by the Government Harness and Saddlery Factory, where they are curried and used for equipment.

There were many faults in this early mixture, which were gradually eliminated by further experiments at Maihar, until in March 1918, the mixture No. 137 (*a*) :—

	per cent.
Aonla twig bark (*Phyllanthus emblica*)	50
Karunda Sumac (*Carissa spinarum*)	30
Dhawa Sumac (*Anogeissus latifolia*)	20

produced fine leathers, similar in colour and strength to *tarwad*, but without the open porous section that *tarwad* leather shows. The time taken to tan with this mixture was longer than with *tarwad*. A small hand-tannery at Kampti, Central Provinces, with only an intelligent *chamar* and an apprentice from Maihar, has succeeded in producing excellent leathers by the use of this combination of tanstuffs.

Work was then directed to find a tanstuff to reproduce a special property of *tarwad* bark, namely, its power to remove lime and to cause "plumping" of the hide, which may be described as "self-bating." Eventually, by the use of *gothar* fruit (*Zyzyphus xylopyrus*), crushed and mixed as a mucilage and applied in a system of pits, where the hides are suspended during 8 days, a successful result was obtained and a saving of three weeks effected in the time of subsequent tanning in mixture No. 137 (*a*).

This treatment, *viz.*, suspension in *gothar* mucilage and tanning to a finish in pack with *aonla-karunda-dhawa*, offers to many tanneries in Northern India a cheap means of producing excellent crust leather. The *tarwad* leather tanner, who has known nothing but *tarwad*, may not be so successful with this owing to the difference

in his methods, but the substitute (mixture No. 137 (*a*), is so near to *tarwad* in its effects, that if only one-fifth of *tarwad* is used with four-fifths of the above tanstuffs, the *tarwad* tanner can produce excellent leather by his own methods. In all, some fifteen rail-wagon loads of this mixture have been so used by *tarwad* tanneries.

The Maihar tannery turned out some 2,000 hides during the early part of 1918, all tanned as described; meanwhile, experiments were continued with the object of imitating *tarwad* even more closely. In *jamrasi* twig bark (*Eleaodendron glaucum*) was found a bark that contains a tannin which dissolves to a thin pale liquor and which has great penetrative power. Like the liquor of *tarwad*, *jamrasi* liquor penetrates the hide in a diffused manner producing an open porous section. *Jamrasi*, however, is relatively low in tannin, and so in order to increase the strength of the tanstuff applied to the hide, experiment was made with mixture No. 172—

	per cent.
Jamrasi	55
Kahua	25
Karunda	20

always with a preliminary treatment in *gothar* mucilage. A large number of hides have now undergone this treatment at Maihar with uniformly good results. The time of tanning is under one month for an average kip. The leather is almost exactly like *tarwad* leather in every way, with an elastic grain and open and porous in section. The results obtained with *jamrasi* at Maihar are, however, still unconfirmed by the parallel experiments in progress at the Government tannery at Bombay, and a final judgment on this tanstuff cannot yet be pronounced.

Further, a large number of these leathers have been re-tanned with *kahua* bark (*Terminalia Arjuna*) and curried, to produce excellent leather. This *kahua* bark is probably the most valuable single tanstuff which has been tested on a large scale so far at Maihar. The writer has devised a special cutter with which the bark of the tree is being taken at two-yearly intervals without the destruction of the tree. The Esociet Company has collected and sold in all 116,000 maunds of this bark, which is now in use in seven tanneries. The tannin of this bark reaches the tanner at just one half the cost of the tannin in other tanstuffs previously used.

It has been found that the tannin of this bark can be applied to produce (*a*) light porous half-tan leather, (*b*) the heaviest fully-loaded leather, (*c*) to re-tan lightly half-tan leathers. Its action is extremely similar to the descriptions of the action of European oak bark, and the chemical reactions are similar in both cases. *Kahua* should, it is expected, afford a fine extract of tannin, especially in admixture with *dhawa* Sumac, with the latter's wonderful bleaching effect.

A long series of experiments to find "the seat of tannin" in many common species of the scrub jungles has resulted in the discovery that in many cases the largest amount of tannin, and that of a pale colour, is to be found in the bark of the top of the branches, thus allowing of the pollarding of the species that will stand such treatment. This may be named "twig-bark," and the best of these are *aonla* twig bark with 24 per cent. tannin, and *jamrasi* twig bark with 12 per cent. and its exceptional non-tan. It is not always the case that the richest and best bark is that from the branches. On the contrary, *kahua* bark is best taken from the bole of the tree, also *babul* bark, and the barks of many oaks are richer when they are taken from low down in big trees. In many cases, the richest tannin is to be found in the leaves.

Attempts are now being made to overcome certain physical difficulties in the collection of *thawai* bark (*Woodfordia floribunda*), which is richest (27 per cent.) at the base of the tree. This tanstuff promises well, but the practicability of the present methods of collection is still uncertain. It cannot be too clearly repeated that it takes much time and involves much expenditure to find the proper practical method of extracting a tanstuff from the jungle. Special methods of application have been worked out for several tanstuffs, which have been particularly successful with *gothar*. Full details of these and other work will be found by reference to Bulletin No. 1, 1918.

Tanning of "dead" hides.

The Research Factory has devoted much attention to the problem of profitable treatment in India of the low-grade, badly-cured "dead" hides, which were, prior to the war, exported in large quantities to Germany, Austria and Italy, where in spite of the wretched raw material, fairly good leathers were produced and large profits earned. During the last four years, great efforts have been made to induce the *chamars* of the States which are interested

in the Esociet Company, to flay and cure properly the hides of cattle that have died a natural death, and these efforts are beginning to shew result. Out of 2,000 hides per month, not more than 5 or 6 used to appear as unspoilt hides. There are now 300 hides each month, which the Esociet Company receives, which would be classified as second-class "slaughtered" hides in Calcutta. In addition to the six States where this good work is going on, five other Durbars have sent *chamars* to Maihar to learn how to deal with hides in a proper manner. The full results from these efforts cannot, however, be expected for many years to come. The principles applied are to prohibit export and then to offer very high prices for good hides and very low prices for spoilt hides.

In addition to the experiments conducted in the manufacture of 'crust' leather, the Research Factory is engaged in training local men to shave, re-tan and dye and finish the better parts of the "dead" hide to finished leather. It is hoped to go further and produce semi-chrome finished leathers. As no skilled workmen have been imported, progress is slow in this direction. Besides this work, the Research Factory is about to experiment with a new tannin extraction process, which, having been proved successful on the 5-cwt. scale, is about to be tried in a new plant on the 2-ton scale, which will be large enough to allow of the study of the financial aspect of the process. A more intensive and highly technical method of vegetable tanning is also being studied, for, though the simple and cheap treatment of Indian hides to 'crust' leather will always be of importance, it is certain that India will adopt more and more the intensive scientific methods of tanning in vogue in other countries, if she is to compete successfully in the world's markets.

The Indian Munitions Board extends an invitation to all those interested in tanning and tanstuffs and tannin extracts to visit the Research Factory at Maihar, where they will be shown the tanstuffs in use and the leathers in process of manufacture. The Director, Esociet Tannin Research Factory, Maihar, East Indian Railway, will be glad to answer any enquiries on the above subjects.

The Future of Tannin Extract in India.

By J. A. Pilgrim, L.T.C.,
Tannin Expert to the Government of India.

The writer was brought out to India primarily for the purpose of preparing solid tannin extracts, more particularly from the mangroves of Burma. His diversion to Maihar has, however, resulted in his becoming closely acquainted with a large number of Indian tanstuffs, and a study of these undertaken in collaboration with Mr. Fraymouth under all sorts of aspects and conditions indicates that there are quite a number of very useful tanstuffs in India, which would nevertheless be highly unsuitable for extract manufacture. On the other hand, there are cases where an extract might profitably be made from a natural material not suitable for a direct application to the hide.

One of the principal reasons for a tanstuff being unsuitable for extract manufacture is that, so often, in spite of its greater bulk, it pays better and costs less to use it as a raw material. As an instance of this, though it does not refer to a tanstuff which had been grown in India, Messrs. Cooper Allen & Co., Ltd., of Cawnpore, found that it cost them less per unit of tannin to import wattle bark from South Africa than to purchase extract made where this particular bark was grown.

It is well known that in Europe, liquor tanning finds the greatest favour; but in India by far the largest number of hides at present tanned are converted into leather in direct contact with the tanstuff, and this especially applies to the crust leathers tanned for the British War Office, most of which have hitherto been tanned with *Cassia auriculata*, the '*avaram*' or '*tarwad*' of Madras and Bombay. There are not wanting, those who believe that an extract-liquor prepared by leaching *tarwad* and concentrating the liquor with the aid of heat and vacuum would not give anything like as good a result as yielded by the twig bark itself; and this opinion might extend to many other Indian tanstuffs. India is blessed with an abundance of them of almost every type, and most districts of

India have their local tanstuffs available, capable of yielding good results. It would be premature, however, to guarantee the results of these tanstuffs, if employed in the form of a solidified extract. By this I do not wish, without proof, to assert definitely that such an extract would *not* be useful. Such work is about to be tried in conjunction with Mr. Fraymouth's new agitator extraction plant, connected to the Government tannin solidification plant, and must greatly enrich our knowledge as to the suitability or otherwise of various extracts. Our plan will be to work through a list of the most promising tanstuffs on as nearly as possible a commercial scale, so as to obtain the most valuable data possible.

In the meantime, I can only lay down the following general principles :—

(1) If a raw tanning material is very rich in tannin, say, 50 per cent. or thereabouts, it will probably not pay to convert it into solid extract.

(2) The leaching and concentration of liquors almost invariably results in a certain amount of oxidation of the tanstuff in spite of the use of vacuum in concentrating. Thus a 50 per cent. tanstuff containing 25 per cent. non-tannins should, when concentrated down to a solid extract containing 19 per cent. of moisture, analyse at 54 per cent. of tannin, and 27 per cent. soluble non-tannins. But it is quite possible that the extra 4 per cent. tannin gained in the extraction would be lost owing to oxidation into "insolubles" and other causes. The principal gain would be that instead of having a large proportion of vegetable matter as insolubles, the third constituent could only be water—with perhaps a *small* quantity of suspended insolubles in the cold solution. But the increased concentration would be such as to affect railway or steamer freight very little. Some 50 per cent. tanstuffs such as myrabolams or *divi divi*, both of them crushed without seeds, will pack very closely, into small compass and I could not recommend the manufacture of extracts in such cases, except when the presence of insoluble particles was objectionable, as, *e.g.*, in the application of the tannins to textile fibres.

(3) On the other hand, presuming a tanstuff to contain, say, 20 per cent. tannin to 4 per cent. non-tannins, such an

extract should, theoretically, yield tannin 66·7 per cent. and non-tannins 13·3 per cent., with 20 per cent. moisture: or 70·8 per cent. tannin and 14·2 per cent. non-tannins with 15 per cent. moisture. The probability is that the actual percentage of tannin in the solid extract would be between 60 and 65 per cent. and this amount from a 20 per cent. tanstuff would indicate that the manufacture of extract from the raw material should be very seriously considered, and studied with a view to ascertaining the sort of leather yielded both by the raw material and extract respectively. Generalising from the above (an analysis of *Hopea parviflora* bark actually had such figures of analysis, and yielded a solid extract with 60·5 per cent. tannin in a small preliminary solidification test conducted some time ago without the advantages of the new plant), I would say that only when the ratio, $\frac{\text{Non tannin}}{\text{Tannin}}$ is less than unity (1), the question of the possibility of extract manufacture begins to come into contemplation, and the higher the proportion of tannin the more is this the case, which brings me to my fourth principle.

4) There are certain tanstuffs, woods, etc., containing a very small proportion of tannin and a still much smaller proportion of non-tannin, *e.g.*, oak wood, the wood of *Xylia dolabriformis*, etc. With a content of about 6 per cent. tannin, this latter material could not be regarded as a direct tanstuff, but, given adequate leaching facilities, there is no reason why it, with a low percentage of non-tannin, should no come in, from an extract point of view. On the other hand, there are tanstuffs such as *karunda* leaves with, say, 10 to 12 per cent. tannin, and 23 to 25 per cent. soluble non-tannins. A 10 per cent. tanstuff having a peculiarly valuable action on leather owing to its non-tannins *could* come into consideration for direct application in the tannery. But the theoretical strength of an extract made from this, concentrated to 20 per cent. moisture, would only be approximately 23 per cent. tannin, and 57 per cent. soluble non-tannins: and, in my experience, no commercial firm

cares to look at a solid extract with less than 50 per cent. tannin, unless in quite exceptional cases.

(5) Such an exceptional case where an extract with less than 50 per cent. tannin *might* find favour, 's where this is manufactured from cheap low-grade material at a minimum cost, the manufacture resulting in the leaving behind of objectionable characteristics of this cheap raw material. An instance of this sort has been the successful manufacture here, on an experimental scale, of a good-coloured solid myrabolam extract containing upwards of 38 per cent. tannin from a practically valueless refuse of myrabolam 'kernals,' dust obtained in crushing, and spoiled 'nuts,' one-third of each.

A tannin extract low in tannins might also come into demand, on account of valuable properties as regards the action of its non-tannins on the pelt. Then there is the case of the various oak extracts on the market, which, though not particularly high in tannin, have nevertheless a very special weight giving property—probably due in part to the non-tannins, though the main factor here would appear to be the power of the tannins to deposit "bloom" within the pelt. In several of the Himalayan oaks, the tannin is but little in excess of the non-tannins, but the well-known properties of European oak bark—on the average less rich in tannin than the Indian barks I have tested—would fully justify experiments in extraction of these barks. The same applies in even a greater degree to the various oak woods, extracts of which are so largely used in Europe at the present time.

Speaking quite generally, extracts are costly to manufacture and do not give as good a colour as raw tanstuffs, hot leaching, as a rule, giving worse colours than cold. I expect that our experiments will show us that such colours as are developed during concentration may be modified by the judicious admixture of other materials in the leach,—a course to be greatly preferred to chemical treatment. But where long-distance carriage is involved, and the extract represents a proportionately great concentration of tannin as compared with that in the raw material, my present opinion is that there—and perhaps there alone—natural extracts will hold their own in the generality of Indian tanneries, though there may, of course, be special cases, as *e.g.*, in the rapid drumming (loading) of

hides, where the extracts may be turned to good account in a tannery otherwise depending on raw tanstuffs.

From purely theoretical deductions based on the analysis figures quoted below, the following tanstuffs would seem to recommend themselves for experiment in extract manufacture :—

TABLE.—*Tanstuffs likely to be suitable for extract manufacture.*

Tanstuff.	Tannin.	Non-tannin.	Theoretical maximum possible percentage of *tannin* in extract with 15 per cent. moisture.
Miscellaneous—			Per cent.
Hopea parviflora (Malabar ironwood) . .	21·71	4·69	70
Terminalia myriocarpa, mature bark . .	24·00	11·00	58
Dhawa (*Anogeissus latifolia*) Sumac . .	30·00	15·00	57
Kahua (85 per cent.)-*dhawa* (15 per cent.) mixture.	23·20	12·45	55·3
Kahua (*Terminalia arjuna*), bark . . .	22·00	12·00	55
Rumex hastatus (Indian canaigre), root bark .	23·18	12·79	55
Rhus mysorensis (a Sumac shrub), bark . .	10·51	11·43	54
Wattles—			
Acacia decurrens, bark	43·27	8·22	71
Acacia dealbata, bark	17·94	7·18	61
* *Mangroves*—			
Carapa obovata	41·00	11·00	67
Ceriops roxburghiana	27·73	8·15	66
Ceriops candolleana	22·60	10·72	58
Bruguiera caryophylloides	18·41	10·49	54
Heritiera fomes (*Sundri*)	7·34	4·36	53
Certain oaks and chestnuts of the Himalayas particularly recommend themselves, for instance :—			
† *Oaks*			
Quercus fenestrata, mature bark . . .	15·85	8·44	55
Quercus incana, mature bark	13·01	6·30	57
Quercus incana, wood	5·00	4·00	47

oves are, as a rule, very variable as to their tannin content, and I should take the last three in the above list, as being distinctly below the average for the respective species. A good fresh average sample ought, therefore, to give rather higher figures of 'possible tannin content' in the solid extract.

A small sample of branch bark of *Quercus semecarpifolia* gave, on analysis, the extraordinary figures of 23·65 per cent. tannin, and 2·63 per cent. non-tannins. This would indicate a possible maximum tannin-content in a solid extract, of 76 per cent., but this excellent possible figure was not borne out by analysis of a larger bulk of the bark received later, and I therefore have not included the figures in the table.

The actual percentage of tannin in an extract always falls short of the theoretical maximum. This is due to changes which take place during extraction and concentration, and the extent to which these changes occur is obviously one of the factors determining whether a raw tanstuff should be converted into extract or not.

The Supply of Timber and Bamboos.

BY R. M. WILLIAMSON, I.F.S.,
Controller (Timber Supplies), Indian Munitions Board.

The supply of timber and bamboos, but not of railway sleepers or firewood, to meet military requirements during the war in India itself and the various theatres of operations in the East and in Macedonia, has been the duty of the Timber Supply Branch of the Indian Munitions Board since its creation in April 1917. In certain cases, civil departments of Government and railway administrations have also been supplied with such materials.

The principles followed have been those defined in the introductory chapters of this handbook, *viz.*, the utilisation as far as possible of the products of the forests of India and the avoidance of unnecessary inflation of prices due to competitive buying by various military and civil departments of Government. This has been achieved by arranging for additional outturn from the forests, rather than buying existing supplies in the market which, owing to the restriction of shipping and railway facilities, have been to some extent curtailed.

Summary of the operations of the Timber Supply Branch.

The statement on the next page summarises the operations of the Timber Branch of the Indian Munitions Board from its organisation in April 1917 to the end of December 1918. In order to enable indents to be met without undue delay (the extraction of timber from the forests being possible as a rule only during certain months of the year) and to season the timber before despatch as far as time allowed, the Board established large depôts in Bombay, Rangoon and Karachi. These have had to be fed constantly by fresh supplies as they were depleted by issues, and the total balance of stock in hand in these three depôts at the end of December 1918 was 51,293 tons, *viz.*, 28,376 tons (including 137,374 bamboos) in Bombay, 14,794 tons in Rangoon and 8,123 tons in Karachi. The various classes of material supplied comprised

TABLE.—*Summary of the operations of the Timber Branch.*

Destination.	Indents received.	*Amount shipped or despatched.	Balance to be supplied.
	(Tons of 50 C. ft.)	(Tons of 50 C. ft)	(Tons of 50 C. ft.)
OVERSEAS—			
Egypt	60,488	58,455	2,033
Mesopotamia	135,830	127,456	8,374
Salonika	15,647	15,647	Nil
Others (Aden, East Africa, Persian Gulf Ports, etc.)	10,308	5,332	4,976
TOTAL (OVERSEAS) .	222,273	206,890	15,383
INDIA	61,501	34,708	26,793
GRAND TOTAL .	283,774	241,598	42,176

timber for structural work, *e.g.*, the construction of bridges, piers, wharves, buildings and temporary huts and lines, telegraph poles and wood of suitable species for boat building and repairs, air-craft and rifle stocks, and bamboos for river-training works, tent poles, lance staves and mosquito poles.

Supply of Indian instead of foreign timber.

The supply of timber to military forces in Eastern spheres of operations was carried out prior to the creation of the Indian Munitions Board by the Military Works Services, about 100,000 tons of timber being supplied, of which roughly 66 per cent. was of foreign origin. On the transfer of this task to the Indian Munitions Board, the general policy was adopted of meeting requirements as far as possible with indigenous rather than imported foreign timber, with a view to economy and the reduction to a minimum of the demands on shipping. At least 95 per cent. of the timber purchased by the Board was grown in India or Burma. This course secured indirectly the further advantages of stimulating the economic exploitation of the forests of India and Burma, of bringing to notice many species

of timber hitherto little known, and of securing for this country the profits arising from the sale and handling of the material. Further, as by far the greater part of the forests here are the property of Government, this policy benefited to some extent the public revenue of the country, while on the other hand the cost of supply was kept low in spite of the largely increased consumption and the unprecedented volume exported. In carrying out this policy the Indian Munitions Board has received the cordial assistance of the Forest Department, without whose energetic co-operation it would have been impossible to meet from this country the heavy and sudden demands made upon it.

Indian timber resources.

Thanks to the wise and far-seeing policy adopted by the Government of India more than fifty years ago, in stopping the unrestricted exploitation of the State forests and their ruthless and wasteful destruction by the jungle tribes and the neighbouring population, the resources of India and Burma in timber and bamboos at the outbreak of the world war, now happily ended, were far more than ample to meet the demands made on them. In this respect India can congratulate itself on its favourable position as compared with Great Britain, where the greatest anxiety prevailed during the war as to the sufficiency of its timber resources and the possibility of importing sufficient to meet the enormous demands for pit-props for the coalfields, building timber for military and munitions work, etc.

Explanation of backwardness in economic development of Indian forests.

On the other hand, the care devoted by the Forest Department to the tending and improvement of the forests during the past half century, necessary and indeed essential as it was to the improvement of the forests, most of which had formerly suffered much from neglect, fire, over-grazing and overcutting, has indirectly made it more difficult to supply at very short notice very large quantities of the beams, sleepers, scantlings and planks required by the military authorities during the war. In the first place, the efforts of the Forest Department and its officers have been devoted rather to protection, and to gaining the necessary knowledge of the habits and requirements of the trees composing the forests, in order to ensure successful reproduction and development, than to the exploitation of the produce. Secondly, the restriction of fellings in the forests has delayed the construction of the necessary tramways, rope-ways and other means of extraction and the erec-

tion of sawmills for the conversion, whether by Government or private agency, of the raw timber to the planks and scantlings required by the consumer. The development of the economic resources of the Government forests has not yet received the attention which it deserves and which it will certainly receive in the very near future. As regards sawing facilities, Burma with its enormous forest resources is far ahead of India proper, possessing more sawmills than the whole of the rest of India. Unfortunately, the need for the strictest economy in shipping has prevented full advantage being taken of the resources of Burma, both in timber and sawing facilities, but that province has supplied about 80,000 tons or 28 per cent. of the timber needed by the Board. The war and scarcity of shipping has affected very seriously the teak trade of Burma, private exports having fallen from 48,528 tons in 1913-14 to 14,559 tons in 1917-18. The demand for timber (but chiefly of species other than teak) for military requirements was, however, of the greatest help to the timber trade in the province, when supplies began to be drawn from this source, as it gave profitable employment to all the existing mills, many of which had previously suspended work owing to the stagnation of the market.

It may be mentioned that the great majority of the timber supplied by the Board has been in the form of sawn beams, planks and scantlings and that the conversion of these has presented great difficulty (elsewhere than in Burma) owing to the limited number of sawmills existing in the west and north of India and the impossibility of importing additional plant. The expansion of the sawing facilities in India proper has been much hampered by the extreme difficulty of obtaining machinery and machine saws from abroad. It is stated that the price of machine saws has increased here tenfold during the last four years, and even at these extraordinary prices the supply has been the cause of great anxiety to millowners. In spite of this fact, a few additional mills have sprung up in Bombay, while the capacity of some others has been largely increased. A firm owning a mill at Jhelum in the Punjab and employed largely by the Board has more than doubled its capacity, while the Forest Department in the United Provinces is constructing a large new sawmill at Bareilly. These developments, however, have been almost entirely mere transfers of existing plant from places where they were not working remuneratively to others where the demand for them was keen, consequent largely on the purchases of the Indian Muni-

tions Board and the general restrictions of imports of ready cut planking and scantling from Europe. They may, however, be welcomed on that very account as tending to the fuller utilisation of Indian resources and the restriction of dependence on foreign supplies. Such developments are extremely desirable, not from any sentimental point of view but because the supplies from Europe, chiefly the Baltic ports, are likely to be very much curtailed during the next few years owing to the exceptional demands in Europe itself for the rebuilding of devastated tracts in Belgium and France and the making up of arrears of building operations in Great Britain and elsewhere.

The general backwardness in the past in the commercial development of the resources of the forests of India has had two unfortunate indirect results, *viz.*,

(1) that measures have never been taken till recently to discover the best methods of seasoning Indian timbers other than teak or (where appropriate methods were known) to apply these on a large scale;

(2) that the value and properties of timber of most of the species found in commercial quantities in India have not become known to consumers generally, this being the case also with the majority of the military officers whose demands the Board has had to meet.

The result of the combined operation of these two causes has been a general preference for the imported article and the uneconomic use, as well as the use in an unseasoned condition, of the Indian timbers.

The seasoning of timber.

As regards the proper seasoning of Indian timbers a notable advance has recently been made by the publication by the Forest Research Institute of the results of careful experiments, which have been in progress for five years. The best method of natural seasoning for one species is not necessarily the best for another, nor is the best method in one province always the best in another with a widely different climate. With some species, girdling the standing trees one to three years before felling is found to give the best results; with others, careful storage in the log for six months to two years before conversion; with others, storage after conversion proves most suitable. The timber of some can only be seasoned satisfactorily

after temporary immersion in water, preferably running water, for weeks. Thus a great variety of treatment is demanded with various species and the best treatment for timber of the vast majority of the species available has yet to be determined experimentally.

Hitherto very little has been done to ascertain whether Indian timbers can be seasoned artificially with success. Such methods are very extensively employed in Europe and America, but chiefly with timber which has already been partially air seasoned. It is by no means certain that the types of artificial seasoning plant in use in Europe and America will prove suitable in India, and here again it is impossible to generalise in a country with such varied climates and such extremes of temperature and of humidity or drought. Experiments are, however, to be made at a very early date by the Forest Department, and would have been carried out ere this but for the difficulty of importing the plant. The merit of these artificial methods of timber seasoning is the saving of time and consequently of capital outlay. It reduces considerably the stock of timber which it is necessary to keep and the land and buildings required for storage. But unless and until such artificial methods are evolved for rapid seasoning, the only course open is to keep timber under proper conditions generally for three years before use, or, in the case of certain species, to girdle the standing trees one to three years before felling them.

Except as regards the girdling of teak before felling, which has been customary in Burma for many years past, though introduced there primarily to render the logs lighter and easier to extract by water, measures have very rarely been taken in India to season timber on a large scale before placing it on the market. Consequently the Indian Munitions Board has found it almost impossible to obtain and supply large quantities of well-seasoned timber of species other than teak, though the deodar, pine and fir timber supplied from the Himalayas has been fairly seasoned owing to the period which elapses between felling and delivery in the plains markets and the acceleration of the seasoning process as a whole, due to submersion in water during floating operations. With species which are very liable to attack by white ants or other insects, or to decay by the attack of fungi during the rains, timber merchants are naturally averse from risking loss by prolonged storage; but these risks are not very serious if proper precautions are taken.

The antiseptic treatment of timber.

Fortunately by far the greater part of the demands on the Indian Munitions Board for timber, other than in the form of railway sleepers, did not demand great durability or immunity to insect attack or decay (fungoid attack). Though seasoned or dry timber is far less liable to destruction by insects and fungi than green or unseasoned timber, there are of course very few species, of which teak, deodar and sal are the most conspicuous, the timber of which is naturally very durable when exposed to such attacks in exposed situations, especially on or near the surface of the ground.

In Mesopotamia, white ants are not prevalent except in the slightly elevated ground, *e.g.*, village sites, which escape annual flooding, and in addition the main demand for timber for building purposes has been for structures of a temporary nature, or for wharves and bridges, for which durability under water was the main requisite. This point is mentioned to draw attention to another and extremely important development which is yet awaited for the economic utilisation of Indian timbers. Numerous experiments have been made in recent years to discover the method of treating Indian timbers antiseptically, which may be economically the best in this country. The results are published by the Forest Research Institute in Forest Records, Volume III, Part II and Volume VI, Part IV. It is to be hoped that in the near future a great advance will take place in this direction with a view chiefly to enabling India to meet its own requirements in railway sleepers and for building and other purposes, where timber has to be used under trying conditions.

Criticism of demands made on the Indian Munitions Board for timber.

It may be noted that some of the indents received from military forces and Superintendents of Ordnance factories have asked for timber in much larger sizes than was actually necessary and of species of greater value than actually required. These faults are common in countries, where timber is abundant and cheap and before the technical properties of the timber of various species available and their real commercial value, are fully known. With increased demand through the development of industries using wood such wasteful habits have to be abandoned. Timber of a species demanded for a special purpose acquires high value and other consumers have to be satisfied with wood obtainable at less cost. Similarly manufacturers not actually requiring timber in exceptionally large sizes learn to use the smaller pieces.

Aircraft timber.

Extreme difficulty has been experienced in furnishing supplies from Indian sources of timber of the superfine quality and special conditions required by the technical advisers of the Royal Air Force. The species generally used in Europe and America are silver spruce, ash and walnut, and the specifications received are based on designs of machines constructed of such timber and on their average physical and mechanical properties. The Board was asked to discover and to supply timber of at least similar character as to weight, strength and elasticity, and the preliminary search has not yet been concluded.

Attention was naturally first devoted to the Himalayan species of the families named, but the result was very disappointing. The quantity of timber of these species available free of knots, resin galls and other defects, absolutely straight-grained and of the desired texture, was found to be so small as not to be worth attempting to collect, especially in view of the practical impossibility, with existing means of extraction and exploitation, of supplying logs of the length demanded or of converting the timber satisfactorily in the forests. The very steep slopes on which trees of these species grow in the Himalayas, often to enormous size, prevent the formation of dense forests. Consequently the lower branches are not killed off when the trees are young and the timber of old and apparently clean boles is found after conversion to contain numerous small knots. The search for suitable timber has therefore been directed more recently to the tropical forests of India and Burma and thus to species of altogether different families to those named. Here fresh difficulties were experienced, especially in finding a suitable substitute for spruce, the wood required in by far the largest quantity. Most serviceable tropical timbers are of much greater specific gravity than those of the spruce family. A great number are also more or less cross-grained, the fibres in many cases ascending, in adjacent but closely interlocked layers, in alternately right and left handed spirals, and not in straight parallel lines. Further most tropical forests are composed of a very great variety of species, and certain species, though yielding wood of suitable character and quality, could not be considered owing to their not offering timber in the required quantity. In addition, the information to hand as to the technical properties of the timber of the various species considered was altogether inadequate as a guide. In fact much research was needed, and this was delayed by inabil-

ity to procure at once specimens of wood of each species of the necessary quality in thoroughly seasoned condition. However, arrangements have been made for the test, on the exact lines required, of timber of about fifty different species, those of twenty-five of these species having now been effected. The earliest tests were made at the Engineering College, Sibpur, but later tests were carried out at the Forest Research Institute, Dehra Dun, where a superior testing machine was available. It was subsequently arranged to have duplicate and corroborative tests made at the Indian Institute of Science, Bangalore. The assistance afforded by these institutions, and especially that given by Mr. R. S. Pearson, I.F.S., F.L.S., Forest Economist, was invaluable.

Tests of small specimens on a testing machine, though most valuable, cannot be accepted as a final indication of the probable behaviour of a timber when used in an aeroplane. Those timbers which give the most promising results on the testing machine must subsequently be tried and reported on by the aircraft manufacturers. It is obvious therefore that some time must elapse before a list of approved Indian timbers for aircraft construction can be drawn up. The investigations so far have shown that the most likely sources of supply are virgin evergreen forests, in which many of the predominant species grow to an immense size with long clean boles of a hundred feet in length or more without a branch. In fact, aircraft construction, almost the most modern of all industries, is likely to find its main sources of raw material in some of the least developed parts of the world.

Timber for rifle stocks.

Arrangements have been made for the supply of walnut half-wrought rifle stocks to the Ordnance Department, and both the Kashmir State and the Forest Department in Hazara division, North-West Frontier Province have recently erected plant for steam-seasoning the wood, the treatment specially recommended and employed in Europe and America in this connection.

The specifications for timber for rifle stocks are extremely exacting. Walnut timber of the requisite quality is unfortunately increasingly scarce, and no Indian timber has yet been proved a fully satisfactory substitute. Further experiments are, however, in progress in the proper seasoning of timber of the two species which appear best adapted for such use, *viz.*, *terminalia bialata* and *pterocarpus marsupium*. In the case of the latter, a difficulty

hitherto experienced has been the removal of a persistent yellow dye, as well as the effective seasoning of the timber, but experiments recently made by the Forest Research Institute with the latter object have proved that immersion in water, preferably running water, for a period of about 6 weeks in the form of planks, sawn soon after felling the trees, followed by careful air seasoning, is not only the best method of naturally seasoning this wood but removes almost the whole of the dye.

The supply of bamboos.

The supply of bamboos for river-training works in Mesopotamia, for tent poles, lance staves, ambulance stretchers and mosquito-net poles has occasioned considerable difficulty, generally owing to previous ignorance as to the localities in which such bamboos were to be obtained and to the lack of any previous organisation of supplies. The supply in large numbers of bamboos of the required thickness of shell, diameter, length and straightness for each class of work, more or less free from blemishes or surface injury has required prolonged enquiry. These specifications, especially in the case of bamboos for lance staves and tent poles, are so exacting that, in order to conceal blemishes and imperfections, dealers have been driven to adopt numerous tricks which it requires an expert to detect. Experience has shown also the necessity for the preservative treatment of bamboos immediately after collection, as without such treatment they are soon ruined by insects. Immersion in crude oil for a short time is found to afford reasonable protection for at least a year or two, as described in Forest Research Institute Pamphlet No. 15 (Forest Zoology Series No. 2). The organisation of supplies and the introduction of preservative or antiseptic treatment on a wide scale appears to merit early attention.

Conclusion.

A popular up-to-date account of the forest resources of India and the working of the State forests is given in a recent Government publication by Mr. R. S. Troup, Assistant Inspector-General of Forests, entitled "The Work of the Forest Department in India." More technical and detailed information is available in the publications of the Forest Research Institute, Dehra Dun.

Textile Supplies.

By A. H. Silver, C.I.E.,
Controller, Textile Supplies.

A special branch to deal with the supplies of textiles, primarily for army requirements, was inaugurated by the Indian Munitions Board in June, 1917. In its earlier stages, the branch took over the supplies of all the textile and allied requirements formerly dealt with by the Army Clothing Department, Ordnance Department and Supply and Transport Department, and at later stages, as the work developed, specialised classes of goods were transferred to appropriate branches. Thus, the provision of all jute textile requirements became sufficiently large to warrant the establishment of a special branch, while later it was found desirable to administer the actual manufacture and provision of made-up clothing from a special Clothing Branch, thus leaving to the Textiles Branch the main duty of purchase and supply to the manufacturing departments. Th only item, other than pure textiles, now handled in the Textiles Branch is that of army boots, the purchase of which does not fall within the province of any other specialised branch.

The purchase of all textile supplies for the army having been centralised, it became necessary also to centralise the purchasing of similar supplies for all other Government departments such as Police, Posts and Telegraphs, etc. This was duly carried into effect, and to-day all Government requirements of any character for all classes of textiles are dealt with at the Board's headquarters. The purchases made in the Textiles Branch amounted to approximately two crores of rupees per month in the latter half of 1918.

Cotton textiles.

Naturally the main Government requirement in India is for cotton textiles, and to-day the whole of these—with the sole exception at the moment of mosquito netting—are supplied from Indian mills. The policy of the Board has been to deal direct with manufacturers, and it has

been found possible to enter into mutually satisfactory arrangements with the Indian mills under which they supply their goods to Government at an agreed-on percentage of profit. The economies effected by the centralization of purchases and the standardization of supplies, coupled with the buying arrangements made with the manufacturers, have resulted in a very large saving to Government.

Much has been done to standardize the various classes of cotton materials for army purposes and to draw up specifications suited to Indian manufacturing conditions. As an example, it may be mentioned that the revision of the specification for pugree cloth allowed of the material being made by every mill in India, and resulted in a saving of over 10 lakhs of rupees per annum, as compared with the price which would have been paid for pugree cloth made to the former specification and which could only be produced by three or four mills in India.

The effect upon Indian mills of the placing of all Indian requirements in India may be gathered from the figures of supply of some of the larger items during the past year which are as follows:—

Khaki dyed drills and pugree cloths	46,500,000	yards
Grey and bleached cloths	9,000,000	„
Webbings and tapes	49,000,000	„
Cotton ropes	11,000,000	fathoms
Flannelette	2,250,000	yards
Cotton canvas kit bags	2,000,000	
Kullas	1,000,000	
Sheets	500,000	
Pillow covers and cases	400,000	
Mattress cases	200,000	
Yarn and thread	400,000	lbs.

In addition to these, some 10,000 tents were supplied monthly. In some cases, the tents were made by mills who supplied their own *dosuti*, but, where the manufacture of tents was given out to contractors, the Board supplied them with the *dosuti* required, and this alone entailed the purchase of approximately 1,750,000 yards monthly.

The hand-loom industry has been utilised to some extent where it was possible to get from that source a suitable material, while the bulk of the webbing and tape was made by village workers.

Woollen textiles.

There are five woollen mills in India, and all of these were under engagement to supply the whole of their output to the Indian Munitions Board. In addi-

tion, a small disused woollen mill was found in Bombay and was requisitioned by the Board to assist mainly in the manufacture of blankets. The total supply of woollen and worsted manufactures in India was, however, insufficient to meet the full requirements of th army upon its present scale and, consequently, it was found necessary to import a certain quantity of woollens from home. These imports were restricted to the quantities absolutely necessary to supplement the total Indian production, while every effort was made to increase the Indian production to its utmost limit. Thus all the five woollen mills agreed to work day and night in order that their machinery should be utilised to its fullest capacity. This has naturally been a serious strain upon the workers, and Government owes them a debt of gratitude for the manner in which they have met the demands made upon them. The yearly supplies made in India now total nearly 6,000,000 yards of woollen and worsted cloths, 5,000,000 items of hosiery such as socks, jerseys, mittens, etc., 1,250,000 pairs of woollen putties, 1,500,000 blankets and jhools, and 50,000 yards of felt. These figures are greatly in excess of anything which was produced in India before the war. The hand-loom industry has been used to increase the supplies of blankets, and by the latter half of 1918 the total supplies of blankets from all sources were nearly 200,000 a month, practically three times the number supplied up to June, 1917. It seems probable that the total supplies of blankets, now provided, use up all the available blanket wool in India. The puttoo industry in Kashmir has also been exploited to its utmost, and the Board takes all the puttoo which can be had from that source.

It was found necessary early in the war to exercise some measure of control over the supplies of wool offered for sale in India, and various orders were passed under the Defence of India Rules from time to time to control the movements of all wool produced in or entering India. The result was to keep prices steady, and, on the whole, purchases made in India have shown great savings as compared with the prices ruling in England for similar goods at the same time.

Boots.

As a general statement it may be said that the whole of the army requirements has been met by Indian manufacture, although during 1918, it was thought desirable to import some 200,000 pairs from abroad in order to safeguard the supply, as the total manufacturing power of India

expanded to its utmost was only barely sufficient to meet the recurring monthly requirements, which amounted to 175,000 pairs. The bulk of these requirements were met from Cawnpore, and the price of the Indian-made boot has been well below the price for army boots made in England. Special efforts were made by the Board to develop the manufacture of army boots in other centres, and, although it was not found possible during 1918 to make any considerable addition to the monthly supply, it is hoped, if necessary, to procure larger numbers during 1919.

Shipbuilding in India.

By Col. J. Maccregor, R.E.,
Controller of Shipbuilding.

The requirements in the matter of water transport of the overseas forces in the East during the last two and a half years, and the need for sea-going tonnage have given a great impetus to the shipbuilding industry of India and Burma. The general extent of the shipbuilding operations may now be divulged, and it is hoped that the following brief account of the work accomplished in this connection by the various engineering and shipbuilding firms in the country may be of general interest.

Rivercraft for Mesopotamia.

It is impossible to refer to all the circumstances which gave rise to the reorganisation of the shipbuilding industry in India, but the events of the first two years of warfare in the East are still fresh in the public mind and will make clear to most why the demand for water transport had become so heavy that, in 1916, the Government of India found it necessary to form a special agency which would be responsible for the organisation of the work of construction. At the outset, this agency worked under the direction of the Railway Board, but the Indian Munitions Board took over the administrative control shortly after its formation (March 1917). The main idea in the formation of this agency was to secure the full co-operation of the engineering trade, and an offer of the Indian Engineering Association to undertake the executive control of shipbuilding resources was therefore readily accepted by Government, and a Board, styled the Indian Rivercraft Board, was constituted at Calcutta, with sub-committees at Bombay, Karachi, Rangoon. Colombo and Singapore.

Arrangements were made by the Indian Rivercraft Board for the construction of a large number of rivercraft and for the reerection at Karachi and Bombay of craft of various kinds sent out from Home in plates and angles. The main portion of this work

was carried out at Karachi, where a large shipyard was laid down with building accommodation for 20 rivercraft.

In Calcutta, the work consisted principally of the construction of 125 foot steel and composite barges, of 50 foot steel barges and of pontoons for two large floating bridges. A large number of motor launches, anchor boats and dinghies has also been supplied.

In Bombay, there have been constructed barges of the 125 foot type both in steel and composite, and also 50 foot steel barges. The re-erection of two sternwheel tugs and of two sternwheel hospital ships was also undertaken, the hospital ships being large and very complicated vessels.

The laying down of the Karachi yard and the expeditious way in which re-erection work was carried out in it are records most creditable to the organisers and to the executive responsible for the performances. In addition to re-erecting a considerable number of 125 foot barges, a large number of pontoons for the floating bridges was despatched from Calcutta to Karachi in plates and angles for re-erection at Basrah. Three sternwheel tugs sent out from England in plates and angles were also re-erected and despatched under their own power to Basrah.

In Rangoon, the committee built a composite barge and a large number of wooden anchor boats, cutters and dinghies and gave much assistance in plant and skilled labour.

The Singapore Committee helped the Board very considerably, not only in meeting large indents for plant of all kinds, but also in obtaining a large quantity of highly skilled Chinese labour.

The Colombo Committee had very few calls made on them, but they gave considerable assistance in the provision of labour and in the inspection for purchase of existing launches and cargo boats.

Shipbuilding.

In December 1917, as a result of enquiries from the British Government as to the capabilities of India for the construction of ocean-going oil-driven ships, sea-going tugs and steam trawlers, the Indian Munitions Board organised its Shipbuilding Branch at Calcutta. The details of the work were entrusted to a Controller of Shipbuilding, whose services were borrowed from the Admiralty. The main function of the Controller was to meet the demand for new craft required for the different Eastern theatres of war, to investigate the shipbuilding possibilities and encourage construction in India, and

to control repairs to ships other than His Majesty's ships and hired transports. In view of the formation of a Shipbuilding Branch of the Board, it was realized that the continued existence of the Indian Rivercraft Board was unnecessary and it was dissolved in June 1918.

Since the organisation of this Branch in December 1917, a considerable number of tugs, motor boats, lighters, mooring boats, anchor boats canoes, dinghies, marine motors, buoys, and spare parts, such as rudders, propellers and shafting, have been supplied to overseas forces; while under its supervision the building of mine sweepers for Indian coast defence purposes was undertaken, six at Calcutta and three at Bombay.

As a result of the Controller's investigations, it was decided that while the construction of wooden sailing ships in India should be encouraged during the war, it was not practicable to undertake the construction of steel and composite steamships owing to—

(1) the necessity for importing the bulk of the steel materials, equipment, etc., as well as the boilers and engines;

(2) the limited and uneconomical size of steel steamships, which would be constructed with the existing facilities in India;

(3) the present heavy demands on engineering establishments for munitions of war, which could not, without jeopardy, be met concurrently with shipbuilding;

(4) the ability of the shipyards at Home to use all available supplies of steel material with results more beneficial to the Empire than could be produced in India.

In order to encourage the building of wooden sailing ships with or without auxiliary power, the Government of India issued a communiqué to shipowners and builders in the following terms:—

"(*a*) Though no guarantee can be given of general immunity from requisition by Government, an undertaking is given by the British Shipping Controller that in the event of any vessel, built in India after the present date, being required by Government, special rates will be paid, taking full account of the conditions under which it was constructed.

(*b*) The Controller (Shipbuilding), Indian Munitions Board, will give on application, and at his discretion, such assistance as he reasonably can in the way of technical advice

and the supply of plans. Moderate fees will be charged for plans provided by the Controller.

(*c*) Timber will be supplied by the Forest Department in Madras, Bombay and Bengal at moderate rates and on easy terms of payment, on the security of insurance policies on the vessels. In the case of Burma, the Deputy Controller (Timber Supplies), Burma, will assist shipbuilders in negotiations for timber with the firms which hold forest leases there.

(*d*) The results of enquiries made by the Indian Munitions Board suggest that canvas of suitable quality for use in sails is not at present produced in India. Such information as is available on this point from time to time will be given to enquirers by the Controller (Shipbuilding): but, unless a suitable canvas can be manufactured locally, the provision of sail canvas will naturally fall under head (*f*) following.

(*e*) Help will be given by the Indian Munitions Board in securing the provision of essential requirements of such metal parts and accessories of the simplest possible construction, as may be procurable in India but which shipbuilders may experience difficulty in getting without assistance.

(*f*) The Munitions Board will support applications for priority for the importation of accessories, such as anchors and cables, for the construction and equipment of wooden ships, which it may be necessary to obtain from abroad.

(*g*) With reference to the Indian Companies Restriction Act, 1918, the Government of India in the Finance Department will ordinarily grant licenses for the flotation of any shipbuilding company, which has a fair prospect of being able to commence operations in a reasonable time."

The communiqué was issued on the 11th July 1918 and copies were circulated to all local Governments, provincial Controllers of Munitions and other authorities concerned. At present, there are under construction in India and Burma 44 sea-going wooden sailing ships, varying from 100 to 1,000 tons carrying capacity, in the following places :—

Burma.—Rangoon and Moulmein.

Madras.—Calicut, Masulipatam, Cochin.

Bengal.—Calcutta, Chittagong.
Bombay.—Versova.

Concrete vessels.

The possibility of constructing ferro-concrete vessels in India was not overlooked. The Controller General of Merchant Shipbuilding advised the Government of India to await the results of the actual sea-going performances of the vessels being built at Home before embarking on construction. The Indian Munitions Board is in touch with the Admiralty with a view to take advantage of their experience as soon as definitely favourable results and suitable designs have been established.

Supply of Railway Materials from India to Expeditionary Forces.

By J. C. Highet,
Controller (Railway Materials), Indian Munitions Board.

Prior to March 1917, the provision of railway material and plant required by expeditionary forces had been undertaken by the Railway Board, who had formed a special war branch to deal with such supplies, with the construction in India of craft for the Inland Water Transport in Mesopotamia, and also with the recruitment of the technical staff required from India for the working of these transport services. On the creation of the Munitions Board, the portion of this war branch which dealt with railway supplies became the Railway Materials branch of the Munitions Board. The figures given in this note include supplies made, while this branch was under the administrative control of the Railway Board.

Supplies of rolling stock, track and bridging material.

It is impracticable to detail all the various items of railway supply; but, since—except in the case of Egypt and Salonika to which only permanent-way materials were supplied—equipment of all kinds for both construction and working has been provided, the assistance rendered by India to railways in theatres of war will be appreciated from the figures for the main supplies given in the table below:—

Table 1.—*Railway track, rolling stock, and bridging provided from India.*

Destination.	Track.	Locomotives.	Vehicles.*	Bridging.
	Miles.	No.	No.	Linear ft.
East Africa	200	55	740	3,700
Mesopotamia	1,031	172	5,030	8,783
Egypt and Salonika	555	..	..	..
Aden	26	3	85	50
Bushire.	70	7	144	540
Total	1,882	237	5,999	13,073

* In terms of four-wheelers. Bogie vehicles have been reckoned as equivalent to four-wheeled vehicles.

Of the rails provided, no less than 770 miles consisted of new and second-hand material made available from railways, and of this 265 miles were obtained from open lines lifted, from time to time, to meet emergent demands. Of the remainder, 1,002 miles were provided from the Tata Iron and Steel Company, Limited.

Fishbolts and dogspikes.

The manufacture of fishbolts and dogspikes was at first distributed amongst several railway workshops but was eventually concentrated in the locomotive workshops of the East Indian Railway at Jamalpur, steel being supplied from Sakchi in the form of billets, which were rolled down at Jamalpur to the required sections. The monthly production was latterly 600,000 dogspikes and from 75,000 to 100,000 fishbolts and nuts.

Sleepers.

In the supply of sleepers, invaluable assistance has been received from railway administrations and the Forest Department. Latterly, the main supply has been from Burma, whence a regular supply of 100,000 broad-gauge sleepers per month has been maintained, besides sleepers of other sizes in considerable quantities.

In the table below, the rolling stock is classified according to gauge :—

TABLE 2.—*Rolling stock supplied to war theatres classified by gauges.*

Type.	4′-8½″.	Metre.	2′-6″.
Locomotives	6	196	35
Vehicles	433	4,950	616

Details of rolling stock supplied.

The rolling stock provided included such special classes as armoured trains, ambulance trains, disinfecting units and refrigerator vans. Of the standard gauge vehicles, 235 were converted from broad (5′-6″) gauge stock, and the remainder specially built. The conversion of one lot of 150 broad-gauge covered goods wagons was carried out in the Carriage and Wagon shops of the East Indian Railway at Lillooah within 11 days. The same shops turned out 15 entirely new brake vans in the short space of 15 days.

A demand for an ambulance train for use on the standard-gauge lines north of Baghdad was met by converting one of the broad

gauge trains in existence in India. This train consisted of 11 bogies. The work was carried out in the Carriage and Wagon shops of the North Western Railway at Lahore and the converted train was shipped from Karachi within two months.

The greater portion of the metre-gauge stock was supplied on the basis of equality of service, each railway administration by agreement being called upon to help in proportion to the quantity of rolling stock in its possession. Latterly, it was found necessary to depart from this arrangement, and the later demands were distributed, in consultation with the Railway Board, to the railways from which it was considered that further stock could best be spared. The diversity of types of vehicles of the same class was kept down by confining the supply of particular classes of stock, as far as practicable, to certain railways, and restoring the balance of supply by transfers between railways in India. The effect of this will be particularly noticeable to an observant traveller on the metre-gauge system of the Bombay, Baroda and Central India Railway, from which the major portion of the stock sent overseas has been drawn. Three metre-gauge ambulance trains, completely equipped at Ajmere, were sent to Mesopotamia. Two of these—each consisting of fourteen 50 ft. bogies—were completed in the short space of 3½ months, notwithstanding the difficulty experienced in securing the requisite materials. Each of these trains provided accommodation for 146 lying-down cases and 30 sitting-up cases as well as for the accompanying medical and railway staff. The third ambulance train consisted of eight bogies and one water tank wagon. Four additional bogies were subsequently provided, which enabled Mesopotamia to divide up the ambulance stock into five complete trains of eight bogies each.

Of the narrow-gauge stock, 14 locomotives and 175 vehicles were provided from a reserve of light railway material, maintained in India, and the remainder supplied by railways. The supply of bridging has been made entirely from railways.

Distribution of steel from Sakchi.

The distribution of the steel production of the Tata Iron and Steel Company has been controlled through this branch. By arrangement with Messrs. Tata and Sons, the Railway Board secured 50,000 tons of the 1916-17 output for Indian railways and out of this 21,000 tons of rails and fishplates were given up to meet the requirements of the forces in Egypt and Mesopotamia. For 1917-

18, the Munitions Board obtained an option, on behalf of Government, on the Company's entire steel output and this was subsequently extended over the year 1918-19. During 1917-18, 97,000 tons of steel in all forms were supplied to Government, out of which 71,000 tons of rails and fishplates and 4,200 tons of other sections were for overseas. During the six months April—September 1918, the total supply was approximately 55,000 tons, out of which 16,000 tons of rails and fishplates and 1,900 tons of other sections were for overseas. Over and above these quantities, a considerable tonnage of steel sections were supplied to engineering firms in India for the fabrication of river craft, workshops and other steel structures for the various forces.

Petroleum.

BY W. W. WATT,

Deputy Controller, Mineral Oils, Indian Munitions Board.

World's supply.

India's share of the world's supply of crude petroleum has been gradually rising. In 1905-07, it was estimated to be 1½ per cent, but at the end of 1911 it had risen to 1·87 per cent. The percentage at the present day will be larger owing to the effect of the war on the Baku (Russian) and Rumanian fields.

India's production of crude petroleum.

The following approximate figures show the large increases in production of petroleum in India within recent years :—

Year.	Gallons.
1890	4,132,000
1895	13,004,000
1900	37,729,000
1904	118,491,000
1906	140,553,000
1911	225,792,000
1917	282,760,000

Indian areas of occurrence.

Petroleum in India is confined to two arcs of folded rocks at either extremity of the Himalayas :—

(1) the Iranian arc on the west, occurring in the Punjab and Baluchistan and continued beyond British limits to Persia, and

(2) the Arakan system in the east, occurring in Assam and Burma and continued to the oil fields of Sumatra, Java and Borneo. In both areas the oil is associated with tertiary strata.

The North-West Frontier.

In 1884-85, efforts were made to develop the oil resources in different parts of Baluchistan, the most promising being near Khotan in the Mari Hills and Moghal Kot in the Shirani country, but in the years 1889 and 1890, owing to the heavy rains flooding the wells in the Khotan district, the wells were only able to produce sufficient oil to fuel the works and were subsequently closed.

Punjab and the United Provinces.

The districts from which oil has been reported are Shahpur, Jhelum, Bannu, Kohat, Rawalpindi, Hazara and Kumaon, but the output has always been small and has latterly averaged only 1,000 gallons. Recently, however, the Attock Oil Company, under the management of Messrs. Steel Brothers, has been successful in discovering oil at Khaur in the Rawalpindi district. The field is not yet developed as a commercial undertaking.

Eastern India: Assam.

In 1899, the Assam Oil Company was formed with a nominal capital of £310,000, and the output of crude petroleum in Assam rose from 623,000 gallons in 1899 to 2,733,000 in 1905. The production since the war has been:—

Year.	Gallons.
1914-15	4,700,000
1915-16	4,564,000
1916-17	5,000,000
1917-18	6,064,000

Early in 1916, the Burmah Oil Company discovered oil in fair quantity at Badarpur in the Chittagong district, but the quality is suitable only for fuel.

Burma.

The most productive oil fields in the Indian Empire which are actually worked at the present day are those situated on the eastern side of the Arakan Yoma, in the Irrawaddy valley. They form a belt stretching from the Magwe district, in which the well-known field of Yenangyaung occurs, through Myingyan, in which the Singu field occurs, across the Irrawaddy into Pakokku, where Yenangyat is situated. Oil is, however, known further south in Minbu, Thayetmyo and Prome, and further north in the Chindwin valley, but, of the last four areas, the only two in which oil has been found in workable quantities are Minbu and Chindwin. The three principal fields in Burma are Yenangyaung, Yenangyat and Singu.

Yenangyaung.

The oil in the Yenangyaung district has been worked by indigenous methods for over 150 years, and even before 1886 the annual yield was generally over two million gallons. Soon after 1887, systematic drilling was introduced, and the output gradually rose to 85,649,000 gallons in 1905. The quantity of crude oil obtained during the 5 years ending 1917 was :—

Year.	Gallons.
1913	200,556,000
1914	174,982,000
1915	198,809,000
1916	199,153,000
1917	176,979,000

Yenangyat.

Very small supplies of petroleum were obtained from this field prior to 1891 when drilling was started by the Burmah Oil Company. Expansion was slow and the maximum yield was obtained in 1903, when the oil won amounted to 22,666,000 gallons. The yield has since dropped considerably and during 1917 only 5,698,000 gallons were obtained.

Singu.

This field came into sudden prominence. The Burmah Oil Company first struck petroleum in this area on October 30th, 1901, at a depth of 1,455 feet, with an initial yield of 9,600 gallons per 24 hours; but, owing to lack of tanks, production did not begin till 1902, when 175,000 gallons were obtained. With the opening of new wells, the output jumped to 5,617,000 gallons in 1903. In 1917, the production amounted to 79,026,000 gallons.

Method of production.

Although it is now known that the Burmese produced petroleum 150 years ago by sinking open wells, the first reference appears to be contained in Dr. Oldham's report on Col. Yule's mission to Ava in 1855. The average hand-dug well measures approximately 4′-6″ square and descends vertically to depths of 200 to 300 feet. The use of a modified diving dress and air pump has enabled the native well-digger to work for 5 to 6 hours in the atmosphere of petroleum gas instead of only a few minutes, as was the case till Europeans entered the field and introduced the native diggers to the diving dress as well as the mirror to reflect the sun's rays down the well. In 1887, systematic drilling with the "American" or walking-beam type of machine was introduced. The first well

was drilled by machinery for the Burmah Oil Company in the year 1898, when oil was struck at a depth of 727 feet and the yield was 1,600 gallons per day of 24 hours. In 1915, this company was compelled, owing to exhaustion of the upper oil sands, to sink deeper wells, and their deepest well in 1915 was 3,150 feet.

In recent years, several of the large oil companies have introduced the rotary drilling machine, which under certain conditions, is more satisfactory.

Method of conveyance.

The old method of conveying the oil from the wells to the river bank was by means of earthenware *chatties*, either carried by coolies or on country carts, but this method was improved upon in 1874, by the construction of what might be termed a primitive bamboo pipe-line. This line was built of lacquered bamboos and the oil was conveyed by gravitation from the wells to a country boat fitted with large earthenware *chatties*. The next advance in the method of transport was made by the Irrawaddy Flotilla Company, which built large flat-bottom barges or flats, on the deck of which the large earthenware vessels were placed. These were afterwards replaced by steel tank barges of about 300,000 gallons capacity. In 1908, the Burmah Oil Company laid a pipe-line 10 inches in diameter and 275 miles long, at a cost of £750,000 from their fields in Upper Burma to their refineries at Rangoon, and installed three pumping stations on the line fitted with Weir's high pressure pumps, which are capable of delivering oil at Rangoon at the rate of 520,000 gallons per day.

Method of distillation.

Before the crude petroleum can be marketed it has to undergo a process of refining by distillation and the products obtainable are shown in the diagram on the next page.

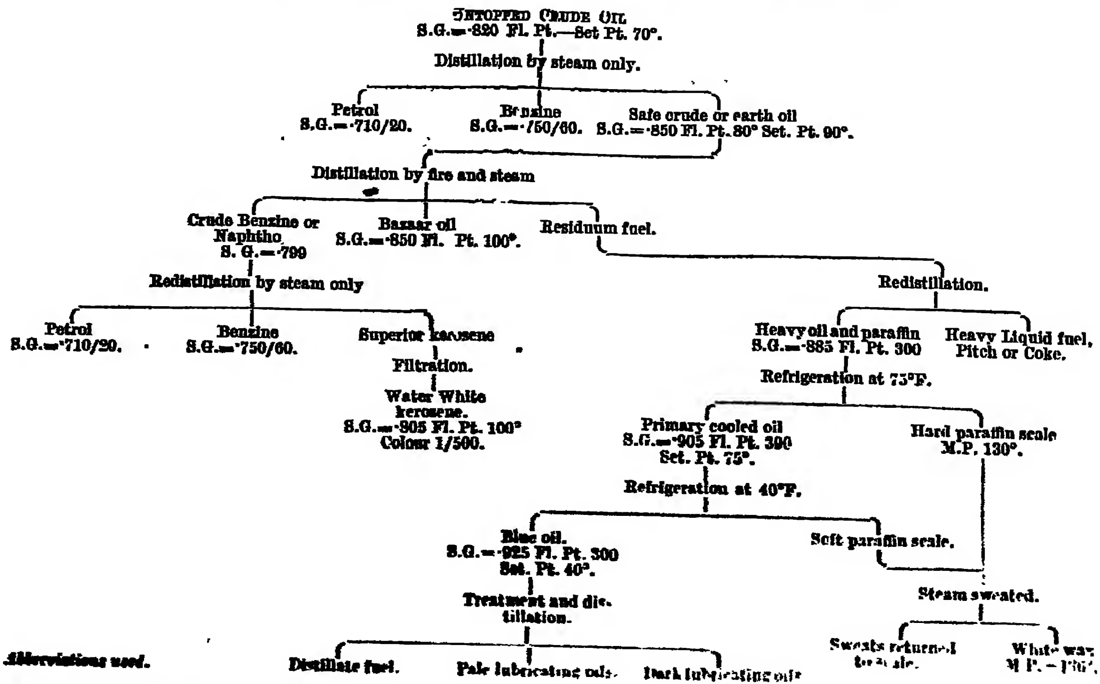
This process diagram is not applicable to all crude petroleum, as the method of distillation to be adopted depends entirely on two factors :—

(*a*) the character of the crude petroleum as revealed by analysis, and

(*b*) the market in which the products are to be sold.

In the early days, the Indian market demanded only a burning oil (kerosene), with the result that small "pot" or intermittent stills were erected and the distillate, irrespective of physical properties, was collected and sold as "lamp oil", while the residue

Diagram showing ordinary process of refining Burma petroleum.



Abbreviations used.

Specific gravity at 60°F.	= S. G.
Flash point (closed)	= Fl. Pt.
Setting point	= Set Pt.
Lovibond tintometer test	= Colour.
Melting point	= M P.

from this distillation was discarded. Later on, the increased production of crude petroleum and the demand for a higher grade kerosene caused manufacturers to adopt more scientific methods, and the well-known system of continuous distillation, patented in 1883 by Mr. Norman Henderson of the Broxburn Oil Company, Scotland, was introduced into Burma and has worked successfully ever since.

With the evolution of the internal combustion engine and rapid progress in the motor car and aircraft industries, petroleum refiners found a market for the lightest portion of the distillate, *viz.*, petrol, which had hitherto been removed at the oil fields by roughly "topping" the crude oil, *i.e.*, removing the lowest boiling point fractions by steam distillation. These fractions had hitherto been a waste product and were destroyed. The new demand necessitated further improvements in the distillation of crude petroleum, and numerous processes have been recently patented to extract the maximum quantity of petrol from the crude oil. One of the latest and most economical methods patented was one introduced in 1915 into the Burmah Oil Company's refineries by Mr. H. L. Allan, Assistant Manager. A short description of this process will be found at the end of this article.

The following indicates roughly the principal uses of the products shown in the diagram :

Undistilled crude oil—in munitions factories for the manufacture of explosives.

Distilled or safe crude—"earth oiling" wooden structures; as a preservative and disinfectant; as fuel oil; for laying dust on roads.

Petrol—for internal combustion engines; motor cars and cycles; aeroplanes; dry cleaning; lamps.

Benzine—for internal combustion engines other than aircraft; lamps.

Kerosene (bazar oil)—for ordinary wall lamps of any make, but mainly for Indian consumption; gas making; engine cleaning.

Superior kerosene—for house lighting; gas engines; etc.

Water white kerosene—a better quality than superior kerosene.

Heavy residuum—as fuel in place of coal.

Pitch—for road making; cable covering; etc.

Coke—as fuel.

Distillate fuel—for Diesel oil engines; army cooking stoves; boilers.

Lubricating oil (in all grades) for all types of machinery.

Wax—in munitions factories; and for candles.

Mineral oils in war.

The great importance of the mineral oil industry in military and naval operations is illustrated by the use of oil fuel in the navy, of benzine and petrol in mechanical transport of all kinds, of petrol in aero-engines, and of mineral lubricants in engines and machinery of every type. Burma has contributed its products for each of these uses, and it is an indication of the magnitude of the output that its petroleum spirit has probably been in use on every battle front.

Manufacture of paraffin wax and candles from crude

Paraffin wax.

As the description of the complete process for the manufacture of paraffin wax would lead to a very long article and would involve the use of technical expressions the following short summary may suffice :—

From the process diagram on page 210 it will be seen that the "residuum fuel" contains most of the paraffin wax. This residuum fuel is distilled and the distillate, which contains nearly all the paraffin wax and lubricating oil, is treated by a refrigerating process to separate those two products. The paraffin wax obtained in this manner requires to be refined to eliminate the oil, and this process is carried out as follows :—The crude wax is run into cakes 2′-6″×1′-0″×2″, and then "sweated" in rooms heated by means of closed steam. The oil "sweats" out leaving the white wax, which only requires decolorizing to yield a pure white wax with a high melting point.

The following uses of paraffin wax illustrate its great importance to industrial concerns :—Beautiful transparent paraffin candles are made from it in Burma in place of the old tallow "dips." The wood used in match manufacture is saturated in it to increase combustibility. Designs are traced with it on fabric before the fabric is immersed in the dye. (i) It is used for lining beer barrels; (ii) frescoe and paper-glazing; (iii) linen starching to produce gloss; (iv) egg, meat, flower and fruit preserving; (v) making model ships to be tested in naval experimental tanks; (vi) waterproofing woollen fabrics; and (vii) for insulating purposes electrical installations. Confectioners also use paraffin wax in glazing paper to prevent the confection adhering to the paper in which it is wrapped.

TABLE 1.—*Showing exports of petrol, benzine and other motor spirits from India from 1913-14 to 1917-18.*

Destination.	Quantity. 1914-15.	Quantity. 1915-16.	Quantity. 1916-17.	Quantity. 1917-18.	Value. 1914-15.	Value. 1915-16.	Value. 1916-17.	Value. 1917-18.
	gallons.	gallons.	gallons.	gallons.	£	£	£	£
United Kingdom	20,626,798	25,190,961	23,783,451	15,245,378	*128,931*	*152,053*	*148,335*	*97,147*
Ceylon	29,096	..	..	..	*2,061*	..	..	..
Egypt	..	..	..	3,689,333	..	..	..	*23,058*
TOTAL BRITISH EMPIRE	20,655,894	25,190,961	23,783,451	18,934,711	*130,992*	*152,053*	*148,335*	*120,205*
Holland	932,351	..	..	..	*5,827*	..	..	..
France	..	..	904,347	..	..	..	*5,652*	..
TOTAL FOREIGN COUNTRIES	932,351	..	904,347	..	*5,827*	..	*5,652*	..
TOTAL (ALL FROM BURMA)	21,588,245	25,190,961	24,687,798	18,934,711	136,819	152,053	153,987	120,205

TABLE 2.—*Showing exports of kerosene from India from 1913-14 to 1917-18.*

	Quantity.				Value.			
—	1914-15.	1915-16.	1916-17.	1917-18.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	£	£	£	£
TOTAL BRITISH EMPIRE	856	..	12	404	*20*	..	..	*12*
Siam	..	..	6,280	..	..	..	*277*	..
Madagascar	..	..	..	11,400	..	..	..	*490*
Other foreign countries	480	80	112	416	*20*	*3*	*5*	*20*
TOTAL FOREIGN COUNTRIES	480	80	6,392	11,816	*20*	*3*	*282*	*510*
Share of India	56	..	116	11,816	*1*	..	*5*	..
Share of Burma	1,280	80	6,288	404	*39*	*3*	*277*	*12*
TOTAL	1,336	80	6,404	12,220	*40*	*3*	*282*	*522*

TABLE 3.—*Showing exports of other grades of oils from India from 1913-14 to 1917-18.*

—	Quantity.					Value.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	gals.	£	£	£	£	£
TOTAL BRITISH EMPIRE MAINLY TO UNITED KINGDOM.	15,383,073	4,587,788	2,917,602	252,723	[illegible]	98,523	31,400	28,369	19,919	5,670
TOTAL FOREIGN COUNTRIES.	*6,925,619	22,356	20,940	36,913	2,985	44,209	1,898	2,441	3,017	150
Share of India . .	1,896	2,295	9,092	2,192	4,063	134	98	734	228	278
Share of Burma . .	22,307,304	4,607,848	2,938,450	317,444	91,512	142,595	33,200	30,076	13,708	5,542
TOTAL	[illegible]	4,610,143	2,947,542	[illegible]	[illegible]	142,729	33,298	30,810	13,936	5,820

* Includes 922,586 to Germany, 3,006,068 to Holland, 2,920,444 to Pacific Coast. Exports to these countries ceased in 1913-14.

TABLE 4.—*Showing imports into India, of petrol and benzine and other motor spirits.*

	Quantity.					Value.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	gals.	£	£	£	£	£
TOTAL BRITISH EMPIRE .	20	..	12	..	124,817	*2*	..	*2*	..	*10,661*
*TOTAL FOREIGN COUNTRIES .	36,855	51,919	50,299	15,312	240,990	*2,799*	*3,445*	*3,353*	*1,524*	*30,913*
Share of India . .	36,635	51,899	50,311	14,312	240,990	*2,776*	*3,444*	*3,355*	*1,504*	*41,574*
Share of Burma . .	240	20	..	1,000	..	*25*	*1*	..	*20*	..
TOTAL .	36,875	51,919	50,311	15,312	365,807	2,801	3,445	3,355	1,524	41,576

* Mainly from America into Bombay, Sind and Madras. The last named Presidency received 224,991 gallons in 1917-18 and nothing in previous years.

TABLE 5.—*Showing imports into India, of kerosene in tins (gallons).*

	Quantity.					Value.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	gals.	£	£	£	£	£
TOTAL BRITISH EMPIRE .	145,807	156,506	143,830	107	16	5,283	5,745	4,058	7	1
* TOTAL FOREIGN COUNTRIES.	15,728,544	12,328,387	12,827,032	4,846,332	4,906,862	590,793	453,475	520.957	241,504	291,245
Share of India . .	14,797,340	11,420,853	11,878,293	11.399.939	4,209,262	558,542	420,312	485,824	230,495	254,340
Share of Burma . .	1,077,011	1,064,130	1,092,069	246,500	697,416	37,534	33,375	39,221	11,016	36,906
TOTAL .	15,874,351	12,484,893	12,970,862	4,846,439	4 906.878	596,076	459.220	525,045	241,511	291,246

* Mainly from America.

TABLE 6.—*Showing imports into India, of kerosene in bulk.*

	Quantity.					Value.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	gals.	£	£	£	£	£
TOTAL BRITISH EMPIRE .	2,195,832	7,758,617	5,935,332	2,945,851	17,935	*56,951*	*198,877*	*163,916*	*106,731*	*945*
TOTAL FOREIGN COUNTRIES.*	50,779,790	60,347,315	49,922,160	41,083,821	24,396,170	*1,251,274*	*1,536,987*	*1,305,830*	*1,420,733*	*871,288*
TOTAL (NONE TO BURMA)	52,975,622	68,105,932	55,857,492	44,029,172	24,414,114	1,308,225	1,735,864	1,469,746	1,527,464	872,233

* Mainly from Persia, Borneo (Dutch), America.

—	Quantity.					Value.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	gals.	gals.	gals.	gals.	gals.	£	£	£	£	£
Total British Empire .	1,422,561	1,306,996	1,208,435	2,457,923	1,583,951	8,908	10,345	9,760	25,991	17,493
Total Foreign Countries.*	6,342,119	8,580,996	9,874,189	17,212,342	18,726,478	59,443	64,452	80,586	171,429	145,578
Share of India . .	7,765,680	7,296,812	7,205,195	12,737,870	14,087,632	68,330	57,480	64,755	130,463	151,649
Share of Burma . .	..	2,584,179	3,877,419	6,932,395	1,221,082	..	17,317	25,581	66,957	11,422
Total .	7,765,680	[illegible]	11,0[illegible],624	[illegible]	15,[illegible],714	68,330	74,797	90,326	197,420	163,071

* Mainly from Persia, Borneo and Sumatra.

TABLE 8.—*Showing exports of paraffin wax from India.*

	Quantity in Cwts.					Value.				
—	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	cwts.	cwts.	cwts.	cwts.	cwts.	£	£	£	£	£
United Kingdom	84,860	107,616	151,340	118,971	93,082	*129,408*	*161,481*	*215,537*	*173,751*	*141,870*
Australian Commonwealth	34,594	27,565	30,432	22,240	51,040	*52,472*	*41,803*	*46,460*	*33,729*	*78,776*
Other British Possessions	75,041	92,808	75,155	122,430	101,800	*104,068*	*127,524*	*108,300*	*181,832*	*248,269*
TOTAL BRITISH EMPIRE	194,495	227,989	256,927	263,641	307,722	*285,948*	*330,808*	*370,297*	*389,312*	*468,315*
TOTAL FOREIGN COUNTRIES	108,653	145,021	116,662	191,226	176,528	*162,788*	*217,327*	*172,180*	*258,645*	*271,586*
TOTAL	303,153	373,010	373,589	454,867	484,250	448,736	548,135	542,477	677,957	739,901

The countries included in "other British Possessions," to which the largest percentage of wax was exported were China (Hong Kong), Africa, and New Zealand. The largest foreign consumers were Japan, America and China (exclusive of Hong Kong). All exports were of wax manufactured in Burma.

Candle manufacture.

When this branch of the industry is carried on as part of the refinery proper, the melted wax is run direct from the filters to the mixing tubs and there mixed with a certain percentage of stearine. Paraffin wax itself becomes plastic under the influence of gentle heat; the stearine is added to increase the rigidity of the candle and to impart a skin, which it would not otherwise possess on leaving the moulds. The wax is run from the tubs into a steam-jacketted pan in which any traces of impurities and water are readily detected, and from which it is lifted by means of a ladle-shaped scoop and transferred to a flat-spouted bucket which delivers an even stream of liquid wax to the candle-moulding machine. This is usually done by hand labour, although in some factories the wax is transferred through pipes.

The candle machine consists of rows of block tin moulds, cast on a very highly polished mandril to ensure that the inside surface is perfectly smooth, and secured into a steel trough which forms the top of the water chamber. The bottom or butt of the candle is flush with the steel plate, and the tip, or shoulder, is formed by a movable polished tip mould. The tip is attached to a hollow piston and is pierced to allow the wick to pass from the wick reels arranged underneath. The pistons rest on a lifting plate, which is raised and lowered by a screw gear fitted at both ends of the frame.

When the melted wax is poured in, sufficient is left in the trough to allow the moulds to fill up as their contents contract in cooling. The temperature of the moulds must not be too low, as air bubbles carried in by the wax will not be expelled, and these will give the candle a pitted surface. After the wax has set, the excess is trimmed off with a knife, the candles raised by the gear, and the exact amount of wick for the next batch of candles drawn into position.

The average machine is capable of turning out 360 candles every 15 minutes (time varies according to the temperature of the cooling water). Some American machines are said to be capable of turning out as many as 800 candles per lift. Coloured candles are obtained by adding organic colouring matter to the wax when melted in the steam pan. Wicks are treated with ammonium nitrate to render them "self snuffing" and also to prevent smouldering after the candle is extinguished.

Allan's petroleum distillation process.

The arrangement shown in the following illustration is suited to the distillation of Burma crude petroleum for petrol (s. g. ·715 to ·720), benzine (s. g. ·755—·760), water white kerosene (s. g. ·800—·810), yellow kerosene (bazar oil) (s. g. ·840—·845),—representing 70 per cent. of the crude oil.

Preheaters.—The object of this apparatus is to preheat the raw crude by utilising the superheat of the vapours from the stills, and may be designed to distil 5 per cent. to 20 per cent. from the crude before entering the stills proper.

Stills.—These are six in number of 6,000 to 12,000 gallons capacity connected in series. The crude oil enters from the preheaters at the first still and flows through the last one, each still distilling off 8 to 10 per cent. The residue from the last still is also utilised to preheat the crude oil. These stills may be fired with oil, gas, or coal and may or may not have steam blown in during distillation. In the general arrangement shown for Burma crude oil, to obtain the products cited, the first three stills have a common vapour pipe and the second three are similarly connected. The crude oil enters at the bottom of preheater P_1 and ascends through the tubes, and is heated by the vapours from the stills marked No. 1. The crude oil then overflows to the bottom of P_2 and ascending is heated by the vapours from stills marked No. 2, thence to the bottom of P_3, in which it is heated by the residual oil flowing from the last still on the bench. From No. 3, the crude oil enters the first of the No. 1 stills. The three preheaters have a common vapour main through which the petrol and the portion of the benzine have been evaporated.

Atmospheric condensers.—The function of the atmospheric condenser is to separate low-boiling point hydrocarbons from higher boiling point hydrocarbons as efficiently as possible, and the principle underlying their design is that this can be better and more cheaply done by slow fractional *condensation* than by fractional *distillation*, the latter being the usual method. By the fractional distillation method, the process is usually *intermittent*; by the atmospheric it is *continuous*.

The former method implies the evaporation of a given volume, of which, during the whole period of distillation, at least three-fourths condenses and returns to the still, *i.e.*, drastic cooling and reheating: the atmospheric method keeps practically the whole of the evaporated

hydrocarbon in the vapour phase until it is purified and leaves the system. The further theories underlying the atmospheric method advanced by the inventor will be found in the specification for the English patent. In the illustration it will be seen that the mixed petrol and benzine vapours enter the atmospheric system at point a, from which they travel to a_1, and in their course deposit the benzine. Petrol is obtained at a_2. The benzine condensed up to final unit a_1 cascades back to a, so that any petrol condensed in the last unit is re-evaporated by the hotter liquid in the first unit at a. The further course of the benzine at a will be explained later.

The vapours, a mixture of white kerosene and benzine from the stills marked No. 1 pass through the body of No. 1 preheater, giving up excess heat to the crude oil, and enter the atmospheric system at point b, and travel through the intervening units b_1, at which point pure benzine passes to the condenser b_2. The benzine which entered the petrol system, and which has run back to a, enters the benzine system at the unit b_1 and flowing back to b is evaporated by the hot kerosene and proceeds to the condensers b_2.

The vapours from stills No. 2, a mixture of white and yellow kerosene, pass *viâ* preheater No. 2 and enter the atmospheric system at c. The yellow kerosene is condensed in the first two or three units and the white oil in the later ones. Any uncondensed vapours proceed to c_2. If a high flash point white kerosene is required and free steam can be applied at the unit at which the white oil is withdrawn, say, No. 4 or 5 in the section c to c_1, and in all the units from 4 or 5 to c_1 the spirit thus obtained at c_2 is a naphtha suitable for commercial motors.

Allan atmospherics can be applied to the distillation of the residual oil for the separation of heavy oil and paraffin* or to the blue* oil stocks for the production of pale lubricating oils, and results have been obtained equal in all respects to the best high vacuum distillation.

The advantages of atmospherics have been proved to be (1) low initial cost of plant, (2) increased capacity of stills, (3) a continuous and practically fool-proof process, (4) uniformity of product, (5) larger yields of motor spirits to a given specification than any other plant, (6) minimum fuel consumption, labour and repairs.

* See process diagram on page 210.

The Manufacture of Calcium Carbide, Calcium Cyanamide and Cyanides in India.

By Dr. L. L. Fermor,

Geological Survey of India.

I—Introductory.

General.

None of these materials has yet been made in India. The extent of the Indian consumption is therefore indicated by the following figures for the five years 1912-13 to 1917-18 :—

Table 1.—*Imports of calcium carbide from 1912 to 1918.*

Year.	Quantity.	Value.	Value per ton.
	Tons.	£	£
1912-13	685	10,131	14·79
1913-14	1,000	14,474	14·47
1914-15	874	12,749	14·59
1915-16	1,118	18,117	16·20
1916-17	888	23,716	26·70
1917-18	642	24,682	38·44

Table 2.—*Imports of potassium cyanide from 1912 to 1918.*

Year.	Quantity.	Value.	Value per ton.
	Tons.	£	£
1912-13	283	24,917	88·04
1913-14	204	22,730	86·10
1914-15	207	18,151	87·68
1915-16	50	5,021	100·42
1916-17	54	5,938	109·96
1917-18	2	593	296·25

The requirements of the Kolar Gold Fields since the outbreak of war have been met by the importation of sodium cyanide, for which the following figures have been obtained:—

TABLE 3.—*Imports of sodium cyanide into India (excluding Calcutta) from 1913 to 1917.*

Year.	Quantity.	Value.	Value per ton.
	Tons.	£	£
1913-14	21	1,821	86·71
1914-15	55	5,141	93·47
1915-16	385	36,930	95·90
1916-17	401	41,478	103·43

TABLE 4.—*Imports of calcium cyanamide or nitrolim since 1912.**

Year.	Quantity.	REMARKS.
	Tons.	
1912	135	The average sale price before or in the beginning of the war f. o. r. Calcutta was £13·33
1913	170	
1914	275	
1915	1,400	
1916	200	
1917	*Nil*	

The published information concerning the methods of producing calcium carbide, calcium cyanamide, and cyanide is fairly extensive, but it is difficult to obtain information as to costs, and as to the minimum economic scale of operations. Thus I am speaking at a guess when I suggest that whereas, judging from the style of plant necessary, it might possibly pay to erect a factory to produce only a few thousand tons a year of calcium carbide in a neighbourhood where

* Figures kindly supplied by Messrs. Shaw, Wallace and Company, Calcutta.

very cheap electric power was already available, *e.g.*, near alumina and aluminium works, it would certainly not pay to undertake the manufacture of calcium cyanamide on a scale sufficient only for Indian demands. On the other hand, the manufacture of calcium cyanamide on a large scale seems to be a very profitable undertaking and new factories, some of which are of very large size, are springing up in different parts of the world. Thus, the world's production of cyanamide in 1914 is stated to have been some 300,000 tons. Two of the largest plants are those of the American Cyanamide Company, which consumes 24,000 H. P. and probably produces about 45,000 tons of cyanamide, and the Odda Works in Norway which is capable of producing, with a consumption of 20,000 H. P., 30,000 tons of carbide for conversion into cyanamide.*

Since the outbreak of war, there has been a great extension of cyanamide plants in both enemy and allied countries, the cyanamide being utilised for the manufacture of ammonia and nitric acid for use in the manufacture of explosives.

If India is to undertake the manufacture of cyanamide, the operations should, therefore, be planned on a scale large enough to satisfy her own requirements and leave a considerable surplus available for export to surrounding countries, such as Java and Ceylon, where nitrogenous manures are of value to sugar planters and others; for, it must be remembered that calcium cyanamide is considered to be a dangerous rival of ammonium sulphate as a nitrogenous manure.

It would need an investigation into the possibilities of the markets of Java, Ceylon and Sumatra, etc., and into the future prospects of agricultural enlightenment in India to enable one to determine the possibilities of this industry.

It seems possible, however, that a factory for the production of 5,000 tons a year of cyanamide would not be too small to be economically profitable, nor too large to find a market for the whole of its production, and in order to have a peg to hang our ideas upon, we may provisionally adopt this figure (see, however, footnote on p. 243). The production of this quantity of cyanamide would, of course, require a corresponding increase in the proposed scale of manufacture of calcium carbide. As about 4,000 tons of 80 per cent. calcium carbide are required for the production of 5,000 tons of calcium

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* Mineral Industry, 1911, page 115.

cyanamide (nitrolim), a plant to produce 6,000 tons of carbide annually would provide all the carbide required by the present Indian market with a margin for export to eastern countries, as well as the carbide required for the manufacture of 5,000 tons of cyanamide.

The smallness of the Indian consumption of cyanides, 250 to 450 tons a year, would probably not operate as a hindrance to the manufacture of cyanides in India, once calcium cyanamide was available, as there seems to be no reason why this operation should not be carried out economically in electric furnaces of small size.

Besides cheap electric energy, the following raw materials would be required for these industries:—

high-grade limestone for lime,
a coal as free from ash and phosphorus as possible,
atmospheric nitrogen,
sodium chloride (if sodium cyanide is to be made), and
electrode carbons.

If the electric energy is to be generated from Mond gas, the consumption of fuel will be several times the consumption of coal or coke used as reducing agent in the formation of calcium carbide. Whereas the fuel required for reduction purposes must be as free from ash as possible, coal of a very inferior quality can be utilised for the production of electric power. It is obvious, therefore, that a works utilising power generated from coal must be situated on the coalfield from which fuel is to be obtained, and as any of the Indian coalfields can provide cheap low-grade coal, that coalfield should be selected which also contains or is near to a high-grade coal, low in ash, and deposits of high-grade limestone.

On this basis, two possible sites for the establishment of these industries suggest themselves. The first is one of the Central Indian coalfields, where the local coal would be used for generation of electric power, and the limestone would be brought from one of the well-known localities in Central India or the Central Provinces. Most of the Central Indian coals have high ash contents. Certain analyses of coals from the Sohagpur field suggest that a portion of the coals of that field may be of high grade; but the only trustworthy information we have of the existence of first-class coal in this part of India refers to Korea. If, therefore, the suggested works were to be erected in this part of India, it would be convenient to choose a site at or near Burhar on the Sohagpur coalfield. Burhar station is

only 22 miles from the point (Jaithari) from which a branch line to Korea State would start, if constructed. From Jaithari to the Kurasia field in Korea is about 50 miles.

The second possible site would be on one of the 'Bengal' coalfields, either the Raniganj field because of the coal of fairly low ash contents there obtainable, or the Bokaro coalfield, if the power company wished to develop its own collieries. Power would be generated from second-class or third-class coal, first-class coal would be used as a reducing agent, and a fairly pure limestone (95 per cent. Ca CO_3) would be obtained from the deposits owned by the Bisra Stone and Lime Company, Limited.

In the previous edition of this handbook, in a joint paper by Dr. Simonsen and myself, it is laid down that power for chemical industries in India should be available at not more than 0·10 annas per k.w.hr. or £3·65 per k.w. yr., if these industries are to stand competition.

So far it has not been possible to devise a method of generating power from Indian coal which would enable energy to be supplied to chemical works for less than £4·75 per k.w.yr. It is possible, however, that in the future hydro-electric installations may be devised, specially designed for electro-chemical and electro-metallurgical purposes, in which power may be obtainable at a figure approximating to £4 or 5 per k.w. yr. or even at £3·65 per k.w. yr. Consideration must therefore also be given to this possibility. Reviewing the distribution in India of high-grade coal, limestone, and water power, three other possibilities suggest themselves. One would be based on the utilisation of the very low-ash coal of Makum (2 to 3 per cent. ash) and the Sylhet limestone, which are situated on opposite sides of the Assam plateau. Their use would depend upon the discovery of a source of hydro-electric power on the south side of the Khasi Hills (or perhaps on the development of one of the adjacent coalfields, such as the Daranggiri field). The Makum coal after conversion into coke would be brought by rail and water transport to Sylhet.

The second possible site would be based on the utilisation of certain waterfalls in Rewa State in Central India, and one of the Central Indian limestones, and probably coal from Korea (possibly from Sohagpur).

Thirdly, we must also not overlook the possibility of the provision of sufficiently cheap power by a scheme in the Western Ghats with

a chemical works on the Konkan coast. In this case the raw materials would be freighted from a distance to the source of power.

Of the five possible combinations of electric power and raw materials referred to above, one of the two schemes dependent on the generation of electricity by the use of coal would be most quickly realisable, as the generation of hydro-electric power in India is often a lengthy process owing to the time occupied in building dams.

There are apparently no valid patent rights protecting the process of making calcium carbide, but the further stages of converting carbide to cyanamide and the latter to cyanides are well protected, and probably much of the necessary plant for all these processes is covered by patents.

Thus, although it will be seen from the sequel that in all probability the manufacture of calcium carbide and cyanamide would prove highly profitable, it would be most desirable to enlist, for the furtherance of such a project, some company or group already manufacturing these products successfully, and in this connection, mention should be made of the Nitrogen Products and Carbide Co., Ltd., a British Company, operating at Odda, Norway, and Alby, Sweden, with a production of 88,000 tons of cyanamide a year. This company claims to have at its disposal sufficient water power for an output of 2,000,000 tons of crude cyanamide.*

The great increase in the world's production of cyanamide resulting from the war will probably lead to severe competition with Chili saltpetre, with cutting of prices. The pre-war price of Chili saltpetre, of £11 to 12 a ton, may be forced down to £9 a ton with a corresponding fall in the price of cyanamide (deduced from the relative nitrogen contents of the two products) from about £14 a ton to about £10. In such a struggle, it will obviously be advantageous for an Indian cyanamide company, to be friendly with one of the existing large cyanamide companies.

II. *Calcium Carbide.*

This compound is made by heating a mixture of quicklime and coke, coal or anthracite in some form of electric furnace (arc or resistance). The proportions depend upon the purity of the lime

* Martin and Barbour, page 61.

and coke, but may be treated as roughly 100 parts of lime to 70 parts of coke.*

The reaction is as follows:—

$CaO+3C=CaC_2+CO$—105,350 calories,

and the temperature necessary for this reaction is variously stated to be 1,600°C and over 2,000°C., but the operation is actually carried out at about 3,000°C (one authority gives 3,300°C).† The carbide is, in some cases, tapped in the liquid condition and after cooling is ground in several stages, of which the later stages are performed in an atmosphere of nitrogen, in order to avoid the risk of liberation and detonation of acetylene gas. The furnaces are of a fairly simple construction and several different designs have been tested, but they all depend for their construction upon firebricks, iron and electrode carbon, with sometimes magnesia. The only one of these materials that should present any serious difficulty in the case of a plant erected in India would be the electrode carbon. This is a difficulty which will arise in all electro-metallurgical or electro-chemical industries established in India. The carbon required in the present case need not doubtless be of such high purity as that required in the manufacture of aluminium, but it would, nevertheless, probably be convenient if an industry for making carbides, etc., were located near the suggested aluminium works, as common arrangements might then be made for the manufacture of electrode carbons.

The consumption of energy was determined experimentally by Borchers on a small scale as 4·0 to 4·3 k.w.-hrs. per kg. of carbide produced, equivalent to a production of 2·19 to 2·04 metric tons of carbide per k.w.-year,‡ and the theoretical yield, assuming the temperature of reaction to be 3,000°C, has been calculated to be 2·4 long tons per k.w.-yr. In actual practice on an industrial scale in large well-managed works, the best yield is 2 tons per k.w.-yr. and the average has been about 33 cwts. per k.w.-yr.§

In our calculations as to possibilities in India, we will adopt a fairly low figure, say, a production of 1·6 tons per k.w.-yr. (= 2 tons cyanamide).

The limestone from which lime is produced must be as pure a possible, and especially, must be free from phosphates. According

* The charge for the production of one ton of carbide is, in one case, stated to be 2,000 lbs. of limestone and 1,200 lbs. of anthracite.

† See Bloxam, page 395; Martin and Barbour, p. 61; Kershaw, p. 70.

‡ Borchers and McMillan, p. 542.

§ Kershaw, p. 542.

to C. Bingham,* the following are the maximum quantities of impurities permissible in a good limestone for carbide :—

	Per cent.
MgO	0·50
$Al_2O_3 + Fe_2O_3$	0·50
SiO_2	1 to 1·2
P_2O_5	0·01

which corresponds to a stone carrying 97 to 98 per cent. $CaCO_3$. In practice, it is difficult to find limestones conforming to all the above points, and limestones carrying up to 1 per cent. MgO and 2 per cent. SiO_2 have been used successfully, but should be avoided if possible. As a guide to the directions in which prospecting for suitable limestones might be prosecuted the following table of analyses is printed. Many of these analyses are based on hand-specimens and small samples and need the confirmation of bulk samples.

TABLE 5.—*Analyses of Indian limestones containing 95 per cent. $CaCO_3$ and over, compiled from various sources.*

Locality.	$CaCO_3$	$MgCO_3$	$Al_2O_3 + Fe_2O_3$	SiO_2 and insolubles.	Other constituents, loss, etc.	TOTAL.	Analyst.
TUFA.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Mahadeopara, Korea State, Central India†.	99·3	0·05	0·50	0·15	..	100·00	Hira Lal.
Piti Nadi, crystalline .	98·5	1·5	0·06		..	100·06	A. Tween.
„ average . .	98·1	1·3	0·8		..	100·2	A. Tween.
Boronga, Singhbhum .	97·86	*Nil* (diff.)	0·63	1·51	..	100·00	Hira Lal.
Near Ranchi . . .	97·3	tr.	..	1·5	1·2 H_2O	100·0	..
„ . . .	96·81	0·14 MgO	0·18	2·87 (including H_2O.)	..	100·00	D. Waldie.
Tulbul, Sirguja State .	96·70	2·05 (diff.)	0·40	0·85	..	100·00	Hira Lal.
Karimati, Umaria coalfield	95·20	2·10 (diff.)	1·05	1·65	..	100·00	Hira Lal.
Champaguri, Assam . .	95·2	..	0·6	3·4	0·8 org.	100·00	A. Tween.

* "Manufacture of Carbide of Calcium," p. 106.

† Limestones that conform to Bingham's criteria, except with respect to phosphorus, concerning the amount of which in Indian limestones practically no information is available, except for those of Sind and some of the Archæan limestones. Whether the limestones of Aden and Elephant Islands conform to Bingham's criteria is doubtful, as the analyses are incomplete.

TABLE 5.—*Analyses of Indian limestones containing 95 per cent. $CaCO_3$ and over, compiled from various sources*—contd.

Locality.	$CaCO_3$	$MgCO_3$	Al_2O_3 + Fe_2O_3	SiO_2 and insolubles.	Other constituents, loss, etc.	TOTAL.	Analyst.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	
CORAL.							
Bellapur, Laccadive Islands*	96·8	tr.	0·7	0·17	2·33 org.	100·0	A. Tween.
EOCENE.							
Rohri, Sind (Khirthar*) .	99·64	..	0·03	0·33	..	100·00	Hira Lal.
Sakhar, Sind* . . .	99·26	0·53	0·28	0·44	0·03P_2O_5	100·54	Mahadeo Ram.
Tsetama, Ramri Islands* .	98·79	0·68	0·10	0·01	..	99·58	T. R. Blyth.
South of Rohri, Sind. .	98·67	0·43	1·02	0·18	0·025 P_2O_5	100·32	Mahadeo Ram.
Chela mouth of Bogapani,* Khasia Hills.	98·60	0·55 (diff.)	0·30	0·55	..	100·00	Hira Lal.
Baumi, south of Sandoway	96·4	..	0·8	2·8	..	100·0	A. Tween.
Sylhet Limestone (Khirthar)	96·15	1·57	0·96	0·76	0·56	100·00	..
Ditto do. .	95·40	1·81	1·72	0·58	0·49	100·00	..
CRETACEOUS.							
Ch. Protheroepur, South Andaman.	96·45	0·09	..	2·80	1·16FeCO_3 0·004S.	100·00	F. R. Mallet.
UPPER JURASSIC.							
Jibal Shiap, Aden† . .	98·8†	..	..	0·4	0·8	100·0	A. Tween.
PERMO-CARBONIFEROUS AND CARBONIFEROUS.							
Tonbo, Northern Shan States*	99·46	0·19	0·39	0·27	..	100·31	T. R. Blyth.
Ditto do. .	99·39	0·16	0·79	0·39	..	100·73	T. R. Blyth.
Moulmein (sent from)* .	98·74	0·71	..	0·58	tr.	100·03	A. Tween.
Nampating, Northern Shan States.*	98·71	0·91	0·43	0·91	..	100·96	T. R. Blyth.
Phalenkoo, Moulmein* .	98·50	1·05	0·55	0·20	0·50	100·80	F. R. Mallet.
Thaton district . .	97·43	1·22	0·49	0·93	..	100·07	C. S. Fawcitt.
Do. . .	97·20	2·35	0·19	0·31	..	100·05	C. S. Fawcitt.
Do. . .	96·65	2·92	0·13	0·32	..	100·02	C. S. Fawcitt.
Ho-un stream, Northern Shan States.	96·00	4·23	0·35	0·35	..	100·93	T. R. Blyth.

*Limestones that conform to Bingham's criteria, except with respect to phosphorus, concerning the amount of which in Indian limestones practically no information is available, except those of Sind and some of the Archæan limestones. Whether the limestones of Aden and Elephant Islands conform to Bingham's criteria is doubtful, as the analyses are incomplete.

†Includes traces of MgO, Fe_2O_3, Al_2O_3, and P_2O_5.

TABLE 5.—*Analyses of Indian limestones containing 95 per cent. $CaCO_3$ and over, compiled from various sources*—concld.

Locality.	$CaCO_3$	$MgCO_3$	Al_2O_3 + Fe_2O_3	SiO_2 and insolubles.	Other constituents, loss, etc.	TOTAL.	Analyst.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
UPPER VINDHYAN.							
Satanwara, Gwalior State .	98·00	1·51	0·12	0·20	0·17	100·00	C. Schulten.
Maihar, Central India .	98·03	1·75	0·06	1·15	0·11	100·00	C. Schulten.
LOWER VINDHYAN.							
Katni, Jubbulpore District	94·65	2·98	..	1·79	tr.	99·42	F. R. Mallet.
CUDDAPAH.							
Wardha Valley (Penganga)	96·8	..	1·2	2·0	tr.	100·0	A. Tween.
Raipur near Bisra, Gangpur	95·18	1·57	1·04	1·87	0·34	100·00	..
ARCHÆAN.							
Elephant Islands, Mergui*.	?pure	*Nil*	..	*Nil*	..	..	E. J. Jones.
Palavanatham, Madura* .	98·24	0·43	0·06	0·57	0·7 (P. tr.)	..	J. L. Simonsen.
Pandalgudi, " * .	97·98	1·00	0·37	0·37	0·28 (P. tr.)	100·00	J. L. Simonsen.
Bilwada, South Mirzapur .	97·92	1·47	0·38	0·80	..	100·57	F. R. Mallet.
Anantagiri, Vizagapatam .	96·73	2·50	0·23	0·56	P. *Nil*	100·02	J. L. Simonsen.
Dodgani area, Mysore .	96·14	2·02	0·76	0·97	..	99·89	Mysore Geological Department.
Ditto. . .	96·02	1·89	0·55	1·65	..	100·11	Mysore Geological Department.
Pandalgudi, Madura .	95·78	2·42	0·25	0·64	0·81 (P. tr.)	100·01	J. L. Simonsen.

* Limestones that conform to Bingham's criteria, except with respect to phosphorus, concerning the amount of which in Indian limestones practically no information is available, except for those of Sind and some of the Archæan limestones. Whether the limestones of Aden and Elephant Islands conform to Bingham's criteria is doubtful, as the analyses are incomplete.

For carbon, charcoal, coal or coke may be used. Charcoal is for various reasons to be avoided, and in nearly all the carbide factories of Europe, anthracite from South Wales is used, and, according to Bingham, should not contain more than 5 per cent. of ash and 0·04 per cent. of phosphorus. Instead, coke containing up to 7½ per cent. ash and 0·04 per cent. of phosphorus may be used, and India, if indigenous carbon is to be used, will probably have to rely on coke. The best Gondwana cokes show considerably higher

ash than the above figures, as may be judged from the following data supplied by Mr. R. W. Church :—

	No. of samples.	*Ash contents*
		Per cent.
Giridih	1	17·00
Lodna	1	12·84
Jharia field	11	15·56—29·62

Giridih coke averages 0·022 per cent. phosphorus, and the first-class Jharia cokes 0·05 to 0·12 per cent. phosphorus.

Makum coal is, however, exceedingly low in ash (2·03 per cent. on 10 samples) and a coke prepared therefrom showed only 0·002 per cent. phosphorus. It is possible, therefore, that a suitable coke might be prepared from coal from Makum or some others of the Assam coalfields. If we exclude the Assam coal, we are apparently faced in India with the following possibilities :—

(1) We must be content to use high-ash cokes (or coal), with the production of a somewhat low-grade carbide.

(2) We must use charcoal, combining our carbide factory with one for wood distillation.

(3) We must import anthracite from Wales.

(4) We must make experiments in washing Gondwana coals in order to separate the bright from the dull layers. An experiment on coal from Barkui in the Pench Valley gave the following result* :—

	Ash contents.
	Per cent.
Banded coal (large sample)	21·61
Bright layers (picked)	1·96
Dull layers (picked)	34·6

Bituminous coals, however, have also been used as such. Thus, the Union Carbide Company has used at the Niagara Falls, Pennsylvania, bituminous coal of the following composition.†

	Per cent.
Volatile matter	35·84
Fixed carbon	53·77
Ash	10·39
TOTAL	100·00

* *Mem. G. S. I.*, XLI, p. 185, (1914).
† *M. & C.E.*, XIII, p. 642.

(This bituminous coal was mixed with lime and agglomerated in a by-product coke oven before charging into the electric furnaces.)

We can, of course, obtain in India coal of as good quality as this (*e.g.*, in Korea and Raniganj), but coal of such high ash contents is not normally used.

The chief uses of calcium carbide are—

(1) for preparing acetylene, and
(2) for making calcium cyanamide.

The only quotations of prices I have been able to discover are the following* :—

1896	£28 per ton f. o. r. Foyers.
1900	£19 " " "
1903	£14 " " "
1906	£14 " f. o. b. U. K. ports.
1911	under £12 per ton in England.
1916	$73 to 75 per ton New York.
1918	£35

Comparing these figures with the values of the imported carbide, it seems probable that the pre-war price of calcium carbide was about £12 to 13 per ton in the United Kingdom or United States of America, and about £14·5 at Indian ports, and we may, perhaps, assume a post-war price of £13·5 in India.

I have referred above to a calculation that electric power could be generated by the use of coal in Central India at a cost of £4·75 per k.w.-yr. If we combine this figure with that adopted for the consumption of electricity for the production of carbide, *viz.*, a production of 1·6 tons per k.w.-yr., the cost of energy per ton of carbide produced works out at nearly £3. The difference between a power cost of £3 and a selling price of £13·5 in India seems to allow ample margin for the other items of cost.

We shall experience great difficulties if we try to draw up a definite scheme applicable to India, because we have insufficient details on many points concerning established practice and concerning Indian materials and conditions, which latter, however, can be ascertained.

Assuming, however, that our works were to be erected at Burhar in Rewa State, that the electric energy was obtainable at a cost

* Kershaw, p. 77; M.I., 1911, p. 115; Metallurgical and Chemical Engineering, XV, p. 718.

of £4·75 per k.w.-yr., that the coal for reduction purposes was brought from Korea and the limestone from Maihar, the following shows the quantities and cost of energy and raw materials required for the production of 6,000 tons of calcium carbide per annum :—

Electric energy 3,750 k.w.-yrs. @ £4·75	17,812
5,500 tons first-class Korea coal @ Rs. 6-8-0*. . . .	2,513
4,711 tons Maihar lime @ Rs. 13†	4,083
180 tons of electrode carbons @ £15‡.	2,700
	£24,408

or £4·07 per ton of carbide.

The above quantity of coal (actually 5,765 tons) is calculated on the assumption that seam 4 of Kurasia with the following average analysis would be used (*Mem. G.S.I.*, XLI, p. 214) :—

	Per cent.
Moisture .	8·66
Volatile matter	30·92
Fixed carbon .	48·86
Ash . .	11·56
TOTAL .	100·00

This coal is, of course, comparable in quality with the Pennsylvania coal mentioned above. But it is recognised that it is of much higher ash contents than is usual for carbide manufacture, and that it might prove necessary to bring the carbide coal from a distance. The Korea field is not yet served by a railway, but probably will be a few years hence. Until the 50 miles or so of railway to the Kurasia field were constructed, it might be necessary to bring coal from a distance.

It may happen, however, that on opening up the Sohagpur coalfield at Burhar, first-class coal will be discovered in quantity

* Rs. 5 for purchase cost of coal f. o. r. Kurasia and Rs. 1-8-0 for freight.

† Cost of lime based on limestone at Rs. 1-8-0 f. o. r. at quarry and freight charge of Rs. 4 per ton. In practice, the smelting company would doubtless attempt to acquire its own limestone quarries. Should any of the Katni limestone be obtainable sufficiently pure and Sohagpur coal be usable instead of Korea coal, the above charges would be reduced.

‡ Figure adopted by Bingham.

sufficient for this scheme, for Reader* gives the following analyses of coal from this neighbourhood :—

	Amlei.	Bokahi (Son).
Moisture .	5·2	Nominal.
Volatile matter	22·2	27·2
Fixed carbon .	57·2	61·0
Ash . .	15·4	11·6
TOTAL	100·0	99·8

Judging from such analytical figures as are available concerning the limestones of Central India and the Central Provinces, that most suitable for our purpose is the Maihar limestone, which according to an analyses supplied by the Maihar Stone and Lime Co., Ltd., runs :—

$CaCO_3$.	96·03
$MgCO_3$.	1·75
$Al_2O_3+Fe_2O_3$	0·96
SiO_2 .	1·15
Loss .	0·11
Sulphur .	..
TOTAL	100·00

With coal and limestone of the quality indicated, the resultant carbide would, if the conversion were complete, carry 83·4 per cent. of CaC_2, the standard at which the carbide appears to be marketed being 80 per cent.

The value of the 6,000 tons of carbide at £13·5 a ton f.o.r. at the works would be £81,000. The difference between this figure and the cost of the energy and raw materials is so large that it seems probable that there would still be a considerable balance left over for distribution as dividends after defraying the costs of working, depreciation of plant, and amortisation of capital. Somewhat similar figures could be worked out for sites in Assam, the Bokaro coalfield, or the West Coast of India.

As an index to the size of the units of plant adopted in at least one case, reference may be made to the works of the American Cyanamid Co., at Niagara Falls, Ontario, where eight 20-ton 3-phase electric furnaces consume 3,000 H. P. each for the production

* Gen. Rep. G S.I for 1899-1900 p 71.

of calcium carbide.* Such large furnaces would probably work very economically and give 2 tons of carbide per k.w.-yr., or $1\frac{1}{2}$ tons per H.P.-yr., or 4,500 tons each annually.†

Working only with the efficiency assumed for Indian conditions of 1·6 tons per k.w.-yr., or 1·2 tons per H.P.-yr., one of these furnaces would produce about 3,600 tons of carbide a year. Two furnaces therefore of slightly smaller capacity would suit the suggested Indian scheme.‡

It has been estimated that the capital cost of the plant required for this scheme, including necessary power installation, would be roughly as follows :—

	£
4,000 k.w. installation with by-product recovery . . .	104,000
Electric furnace, grinding apparatus, buildings, etc. . .	30,000
TOTAL .	134,000

This is probably about the smallest installation that could be economically employed, and if a large enough market for cyanamide could be assured, it would be better to design the plant for a production of 10,000 tons of carbide. The power installation is assumed to be a portion of a larger scheme designed for electro-metallurgical purposes.

III—*Calcium Cyanamide.*

Calcium cyanamide may be produced either by heating calcium carbide in an atmosphere of nitrogen or by heating lime or chalk with charcoal in a current of air. The former method seems to be the one generally adopted and in carrying this out, there are two chief methods. One is to raise the powdered carbide in retorts heated externally by gas to a temperature of 800° to 1,000°C., whilst a stream of nitrogen is forced into the retorts. This method seems to be going out of use, chiefly for the reason that, the reaction between the carbide and nitrogen being exothermic, the temperature, once the reaction has commenced, rises rapidly and is difficult to control ; and, as the reaction is reversible at 1,400°C., the product may contain less than the full quantity of cyanamide.§

*M. & C. E., XIII, p. 218. This outline gives a plant of a cyanamide works.

† The total annual production of this Company, on this assumption, would be 36,000 tons of carbide or 45,000 tons of cyanamide.

‡ But probably, judging from p. 30 of C. Bingham's work, four single-phase furnaces (one in reserve), consuming 1,250 k.w. each would be suitable, or better still furnaces using D. C., as this type of current would be required for the aluminium industry.

§ Martin and Barbour, pp. 61-67 ; Knox, pp. 88-102.

The second method is to heat the crushed carbide in vertical retorts (holding 300 to 500 kg. each at the Odda Works) to a temperature of 800°C. by means of carbon rods acting as an electrical resistance, whilst nitrogen gas is passed in under slight pressure. When the temperature tends to rise too high, the electric current can be switched off and the temperature of 1,400°C avoided. The reaction is as follows :—

$$CaC_2 + N_2 = CaCN_2 + C.$$

The liberated carbon is in the form of graphite. The solid coke-like block of cyanamide is ground into fine powder in an air-tight mill, after which it is stored in a large silo until required, when it is packed in bags with a double lining and sent into commerce under the name of *nitrolim*, which contains :—

$CaCN_2$	= 57 per cent. to 63 (= 20 to 22 per cent. nitrogen).
CaO	= 20
Carbon (as graphite)	= 14
SiO_2, Fe_2O_3, Al_2O_3 etc.	= 7 to 8

The nitrolim should be free from unchanged calcium carbide and free lime.

The nitrogen required is prepared in two ways. The older method depends upon passing air over hot copper, which retains the oxygen as oxide of copper, which is afterwards reduced to copper by means of water-gas. The newer method, which is being generally adopted, is to liquefy air in a Linde or similar plant and separate the oxygen and nitrogen by fractional distillation. The nitrogen thus obtained is mainly used for converting the carbide into cyanamide; but a certain proportion is required for the final grinding of the carbide, as already mentioned.

The reaction by which carbide is converted into cyanamide is an exothermic one, in consequence of which the energy consumed in converting carbide into cyanamide is much less than that required for the production of the carbide used.

One statement as to consumption of energy is that 6 to 7 k.w.-hrs. are required to fix one lb. of nitrogen as calcium cyanamide (including consumption of energy in making calcium carbide).* This means a consumption of from 2,352 k.w.-hrs. to 2,744 k.w.hrs. per ton of cyanamide, which figures are equivalent to a production of

* M.I. for 1910, p. 64.

approximately $3\frac{1}{2}$ to 3 tons per k.w.-yr. According to another statement, two k.w.-yrs. are required to obtain one ton of nitrogen in the form of nitrolim.* This is equivalent to a production of 2·85 tons of cyanamide per k.w.-yr. An average figure realised in practice seems to be that one H.P.-yr. will produce two tons of calcium carbide, equivalent to a production of 2·67 tons per k.w.-yr. Thus it is stated that in Norway 100,000 H.P. is being harnessed for the annual production of 200,000 tons of cyanamide.†

If we accept 2·67 tons per k.w.-yr. as a good average figure and compare this with the figure of 2 tons of carbide per k.w.-yr. (=2·5 tons of cyanamide) given above, it is seen that the consumption of energy in the conversion of carbide into cyanamide must be very small, as would be expected. Since we are considering the installation of only a small plant, we must adopt a figure for the production of cyanamide corresponding to the figure adopted for carbide. Two tons of cyanamide are the equivalent of 1·6 tons of carbide. In adopting these two figures, we are not making any allowance for the relatively small amount of energy required to convert the carbide into cyanamide, but as the final figure adopted is well below the average figure for cyanamide, this does not matter.

As the consumption of energy for conversion of carbide into cyanamide has been allowed for in the cost of producing carbide, because no separate figures are available, and as I have been unable to find any quotations of the market prices for the cyanamide in Europe and America, and we have no idea as to the cost of the necessary plant, it is not possible to enter closely into the financial aspects of the conversion of carbide into cyanamide. As, however, the profit accruing from the manufacture of 4,000 out of the 6,000 tons of carbide would have to be attached to the cyanamide industry, there is little doubt that this would be profitable, if a market could be found for the whole of the production.

IV—Cyanides.

Potassium and sodium cyanides are now made in several ways dependent on the source of the nitrogen,‡ but the only method that

* Kershaw, p. 89.
† Martin and Barbour, p. 61.
‡ Martin and Barbour, p. 72.

we need consider here is the process of manufacture from nitrolim. Where nitrolim is fused with carbonates or chlorides of sodium or potassium, the corresponding cyanide results. In practice, common salt is usually employed, the reaction being as follows :—

$$\underbrace{CaCN_2+C}_{\text{Nitrolim}}+2NaCl=CaCl_2+2NaCN,$$

90 to 95 per cent. of the cyanamide being converted into cyanides. The product, containing 30 per cent. of NaCN,* can be used for gold extraction. There are certain difficulties connected with this process due to the possibility of reconversion of calcium cyanide into nitrolim and of nitrolim into carbide. These difficulties are stated to have been overcome by "using appropriate appliances for melting and cooling the materials," and the conversion of cyanamide into cyanide is stated to be practically quantitative.†

If pure sodium cyanide is required, the fused mixture is decomposed by acids and the liberated HCN absorbed in caustic soda. For the purpose of gold extraction, it appears to be a matter of indifference whether the metal of the cyanide is sodium or potassium, as the cyanide is really used for its CN contents. The figures of imports of potassium cyanide and sodium cyanide shown on pages 224 and 225, illustrate this point, and during the war the sodium compound has been to a great extent substituted for the potassium compound.

As no advantage, financial or technical, is derived from using the potassium instead of the sodium salt for gold extraction, any cyanide made in India for this purpose should be the sodium salt, and as apparently the mixture resulting from the fusion of nitrolim and salt is effective for gold extraction,† it would probably be unnecessary to undertake the purification of the cyanide, although this presents no technical difficulties, as long as precautions are taken to avoid the effects of hydrocyanic acid on the workmen.

Unless we know the average CN contents of the imported cyanides, we cannot tell how many tons of the above mixture would be required annually to satisfy the Indian consumption. The equivalent, however, of every hundred tons of 98 per cent. NaCN would be some 330 tons of the mixture (assuming it to contain

* One source gives the NaCN as equivalent to 25 to 30 per cent. KCN ; Mineral and Chemical Engineering, XIII, 757.

† Martin and Barbour, p. 78.

30 per cent. NaCN), requiring for its production the use of about 157 tons of nitrolim; so that the production of the equivalent of 250 tons of NaCN annually would require the use of about 394 or, say, 400 tons of nitrolim.

As with the manufacture of cyanamide, no definite scheme for the preparation of cyanide can be suggested owing to lack of information as to details. But the difference between the pre-war values of calcium carbide in India of £14·5 a ton and of potassium cyanide of £87 a ton is so large that it would probably pay to manufacture cyanide even on such a small scale as the equivalent of 250 tons of 98 per cent. NaCN annually.

Investigation may show that the gold mines of Sumatra also use cyanide, in which case an attempt would naturally be made to supply this demand also.

As a check on the value ascribed to the cyanide imported into India, mention may be made of the pre-war prices of 40 cents. a lb. *ex* vessel for cyanide imported into the United States in 1911, and of 15 cents. a lb. in Ontario, equivalent roughly to £65 and £70 a ton. The difference between these figures and those for the Indian imports may be due partly to a difference in the average CN contents.

V—*Summary*.

The foregoing note is the result of a preliminary investigation into the possibilities of manufacture in India of calcium carbide, calcium cyanamide, and sodium cyanide. Lack of detailed information prevents the setting forth of a definite scheme showing costs and possible profits, except in the very approximate manner attempted at the end of this summary. But such figures as are available suggest that there would be a considerable margin of profit on the manufacture of calcium carbide in India, in consequence of which it would probably pay to manufacture not only all the carbide required in India, but also other products manufactured from carbide, namely, the impure calcium cyanamide known commercially as nitrolim, and sodium cyanide. It is thought, however, that the Indian consumption of these materials may not be sufficient to justify the installation of an economic unit of plant. Consequently, the proposal is made that the plant should be designed to produce

6,000 tons of carbide annually, which would be disposed of as follows* :—

6,000 tons calcium carbide –
1,000 tons for sale in India,
1,000 tons for sale in Eastern Markets,
4,000 tons for transference to the cyanamide factory yielding 5,000 tons nitrolim to be utilized as follows :—

5,000 tons nitrolim—
4,000 tons for sale as manure in India, Ceylon, Java, Sumatra, etc.
400 tons for conversion to sodium cyanide.

Four possible sites for such an industry are mentioned, two using electric power generated from Mond gas, and two using hydro-electric power. The site selected for investigation is Burhar in Rewa State. The production here of 6,000 tons of carbide annually by the use of electric power generated from Mond gas with recovery of ammonia as sulphate, would require :—

	£
Electric energy—	
4,000 k.w.-yrs. at £4·75 per k.w.-yr. (from 24,000 tons low-grade coal)	19,000
For production of carbide—	
5,800 tons of first-class coal at Rs. 6-8-0	2,513
4,711 tons of lime at Rs. 13-0-0	4,083
180 tons of electrode carbons at £15	2,700
For production of cyanamide—	
1,750 tons of liquid nitrogen—cost of production not known—original value *nil*	...
For production of cyanide—	
431 tons of salt (duty free) at £1·5 approximately . . .	647
TOTAL .	£28,943

The quantity and approximate value of the products, annually, would be—

	£
2,000 tons of calcium carbide (80 per cent. CaC_2) at £13·5 .	27,000
4,600 tons nitrolim (20-22 per cent. N) at £12·2 . . .	56,120
825 tons sodium cyanide mixture = 250 tons NaCN at £70 .	17,500
TOTAL VALUE OF PRODUCTS .	£100,620

* Judging from information received since this note was written, the scale of operations suggested is too small and should be at least twice as extensive. This would mean a greater reliance on export to commence with.

Above it was estimated very roughly that the power and carbide sections of the scheme would cost £134,000. It is very difficult to obtain reliable information on such matters, but from a careful analysis of the very imperfect data available, it seems likely that the capital outlay on the cyanamide and cyanide plants would be about £50,000 and £5,000 respectively.* The total capital outlay required for the whole scheme would then be—

	£
Power plant	104,000
Carbide plant	30,000
Cyanamide plant	50,000
Cyanide plant	5,000
TOTAL	£189,000

On this basis the annual outlay would be roughly—

	£
Cost of energy	19,000
Cost of materials	9,943
Labour and administration	12,000
Depreciation at 10 per cent. on £85,000	8,500
Repairs and renewals at 3 per cent. on £85,000	2,550
Packing in drums 2,000 tons of carbide and 825 tons of cyanide mixture @ £1·5 per ton	4,238
Packing in bags 4,600 tons of nitrolim @ £0·5 per ton	2,300
Loss in dust (carbide)	1,050
TOTAL EXPENDITURE	£59,581
Value of products	100,620
Therefore, profits	41,039
To this must be added 5 per cent. interest on capital cost of power plant (£104,000) included in cost of power	5,200
TOTAL PROFIT	£46,239

The above figures show a profit of 48 per cent. on the capital cost of the chemical plant alone, or of 24 per cent. on the total cost of chemical and power plants. The data on which this estimate is based are admittedly inadequate, but the figures are probably approximately of the right order, and the amount of profit shown leaves an ample margin for such charges as interest on cost of acquisition of land, for increased cost should this enterprise be

* The estimates of capital costs are presumed to be on a pre-war basis.

undertaken under abnormal conditions, or for decrease in the value of the products after the war should there be cutting of prices due to over production in Europe. The figures, however, are sufficiently encouraging to show that the scheme outlined in this note is worthy of serious investigation by duly qualified people.

In this note no consideration has been given to the further industries dependent upon nitrolim or calcium cyanamide as raw material, *viz.*, the manufacture of ammonia from cyanamide, with conversion into ammonium sulphate, nitrate or phosphate for use as fertilizers, and the further oxidation of ammonia to nitric acid by one of the Ostwald group of processes for the provision of the nitric acid required in such large quantities in the manufacture of explosives, amongst which ammonium nitrate may be mentioned.

Before any such scheme as that outlined in this note can be carried out, very careful consideration will have to be given to the competitive effects of ammonium sulphate obtained as a by-product from coke ovens, and *viâ* the Haber process.

It is only necessary to make a passing reference to the industries dependent upon cheap supplies of acetylene derivable from calcium carbide, such as the manufacture of acetic acid and acetone, and the use of the oxy-acetylene flame for welding, liquid oxygen suitable for this purpose being obtained as a by-product in the manufacture of calcium cyanamide.

Should the scheme here outlined be subsequently supplemented by the plant necessary for the production of ammonia and nitric acid, we should be providing India with a very desirable Janus-like or double-faced scheme capable of providing fertilisers in times of peace and explosives in times of war.

The works consulted in preparing this note are as follows:—

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(4) J. B. C. Kershaw; Electro-metallurgy, (1908).
(5) H. Moissan: The Electric Furnace, (1904).
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Paper Making in India.

By M. J. Cogswell,
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From the time that palm leaves and birch bark ceased to be used as writing surfaces, it is clear that manufactured paper of various kinds has been used in India. The Chinese are credited with making the earliest known paper. The Mahomedans of Central Asia borrowed the art from them, and with the Mahomedan invaders of India paper came. The "Sayings of Mahomet" (*circa* 866) are known to have been recorded on paper, but the oldest paper manuscript found in India dates from the first quarter of the thirteenth century. Thereafter, for many centuries, paper making by hand was a fairly flourishing industry in many parts of India, especially in the Punjab. The numbers of men employed in the industry were considerable, as is shown by the fact that in all the principal centres of manufacture arose separate villages or mohallas called after the material.

Hand-made paper.

The hand-made industry survives to the present day and the methods employed are practically unchanged. The long-shaped book in which the village *bania* may be seen entering up his accounts is probably familiar to most of us. Bound ordinarily in a rough red cloth, its leaves are of a coarse tough *badami* paper. Formerly made mainly of old rags, and hemp and jute waste, the present day article consists largely of waste paper, repulped, and strengthened by an admixture of fresh fibre. The manufacture of this country paper at one time constituted a leading jail industry, and quite lately this form of labour has been re-introduced into certain jails. The work is carried on without the aid of any machinery of modern invention. The fibres are cut by hand, are pounded by the aid of a lever worked by men's feet, beaten and further disintegrated by the feet of men in sunken troughs, and then, when the pulp is ready for the makers, it is gathered in a hand mould or tray that is probably identical with that used by the very earliest paper makers.

In Europe, the hand-made paper industry remains one of some importance and continues to produce the highest grade paper for account book and drawing purposes, but there is probably little or no commercial future for its Indian brother. Ten years ago, Mr. Kirk in his "Monograph on Paper Making in the Bombay Presidency" declared that "it is practically habit alone which has prevented the industry from dying out utterly. A few *banias* still use hand-made paper, but only because they hesitate to break away from the customs of their fathers." The intervening years, but for the war, would have hastened the process of decay, and though the high price of machine-made paper has given a temporary stimulus to the old methods, the effect is probably no more enduring than that of a draught of oxygen to a dying man.

Machine-made paper: its history in India.

The commercial future of Indian paper lies with the machine. It was in 1798 that Louis Robert invented the cylindrical paper making machine, and in 1803 Fourdrinier made his first improved machine, which, in essentials, remains the standard to the present time. At an earlier stage, however, machinery had to some extent entered into the operations of paper making, and in 1716 a paper mill on European lines was opened at the Danish settlement of Tranquebar in the Tanjore district, mainly for the purpose of supplying paper to the printing press opened by the mission at that place. According to the Gazetteer, this press still remains, though the paper mill has long since disappeared.

Next, in 1811 or thereabouts, another mill on European lines was established at Serampore, in the Hooghly district of Bengal—also in connection with missionary effort. Its product was obviously of a distinctive sort, since to this day the Calcutta Stationery Office receives occasional demands for "Serampuri paper." Very little information is forthcoming regarding this mill, but from the fact that the *chhapris*, or moulds or sieves, used for the making of paper by hand, still come from Serampore, I deduce that the paper formerly made at that place was hand-made, though the organisation of methods assured a larger output of a paper with little variation in its characteristics.

It is not until 1870 that we have record of a mill for the production of machine-made paper. In that year, the Bally Paper Mills started with one machine. The company was floated in England, and for a considerable period it proved very successful. Other

machines were added and eventually there were four. The maximum output of the mills at their prime was about 5,400 tons per annum. In 1905, these mills closed down; two of the machines were taken over by the Titaghur Mills, and the other two were scrapped.

In 1879, the Upper India Couper Paper Mill at Lucknow was established. It started with one machine, and a second machine was added in 1894. Both machines continue to be in use, though the older one has necessarily seen its best days. The maximum output of the mills is 3,300 tons a year, with a tendency to decrease as the machines grow more decrepit.

In 1881, the Maharaja Scindia established a mill at Gwalior, with one machine. This enterprise has had a very chequered history. For a number of years the mill was closed down. It has recently been taken in hand by Messrs. Balmer, Lawrie and Co., the Managing Agents of the Bengal Paper Mills, and can produce about 1,200 tons of paper a year.

In 1882, the Titaghur Paper Mills were floated as an Indian company. Starting with three machines, the company in 1902 absorbed the Imperial Paper Mills at Kankinara and in 1905 added two machines from the defunct Bally Mills. There is now a total of 8 machines working, with an output of roughly 18,000 tons of paper a year.

Next came the Deccan Paper Mills at Poona, a one-machine mill established in 1883, and producing about 1,000 tons of paper a year.

In 1890, the Bengal Paper Mills started at Ranigunge with one machine. A second was added in 1892 and a third in 1900; and the total output is now some 7,000 tons per annum.

In 1892, the Imperial Paper Mills, already referred to, were started. Three machines were put down and the buildings and equipment generally were considered to be thoroughly up to date. But the business never prospered, and in 1902 it was taken over complete by the Titaghur Company.

There are also in Bombay itself two other paper mills. One at Girgaum has one old machine and is employed almost entirely in the making of heavy brown paper, which is utilised for the manufacture of rollers for ginning cotton. Another mill has been established in the last few years by Messrs. D. Padamjee & Sons. It is a break-away from the Deccan Mills, and has one machine. The water supply is obtained from the municipal mains. Wrapping

papers form the principal portion of its output, but during the current year the proprietors have undertaken to make 350 tons of paper of various sorts for the Bombay Government. Again, at Surat, there is another small mill, but its condition is such as to make working very intermittent and its output is negligible.

Finally at Punalur in Travancore, there is one more small mill, with a machine of doubtful reliability, where brown wrapping paper is produced. It is all disposed of locally at high rates now, but under normal conditions there would not seem to be any remunerative market for its output, and indeed before the war the mill only worked spasmodically.

This completes the list of Indian paper mills, and it will be seen that the total output of all the mills that can be considered seriously aggregates roughly 30,000 tons a year. The total demand for paper in the country is put at about 75,000 tons a year, so that very nearly two-thirds of the pre-war requirements had to be imported.

Notwithstanding the fact that India undoubtedly produces an enormous variety of suitable paper-making materials, the existing Indian mills were consistently undersold before the war in many descriptions of finished paper, and further they made use of a great quantity—some 13,000 tons in the year 1913—of imported wood pulp. The industry was without question in a very shaky condition. The dividends of the Titaghur Mills were *nil* for the three years 1913-14-15, and though in the same years the Bengal Mills paid 6 per cent. the capital had been written down from Rs. 100 per share to Rs. 25. The Couper Paper Mills paid dividends, but put practically nothing to depreciation or renewal account, and the Poona Mills also were taking the last ounce out of their machinery, with no provision for the future.

Raw materials.

And so, despite the fact that for a number of years past Government had been conducting investigations as to the utilisation of new fibres, and specially bamboo and wood pulp, no really practical advance in the commercial exploitation of India's great natural resources had been made. Concessions were applied for and sometimes granted; schemes for the pulping of bamboo, *baib*, spruce, bagasse, hemp stalks, and at least eighteen varieties of savannah grasses were examined and debated; but the only visible results that came to my notice in fourteen years were a small book printed on paper made from bamboo, embodying the results of Sindall's

"Enquiry into Bamboo in Burma," a few sheets of paper representing the results of trials with bamboo in the Titaghur Mills, and the laboratory samples produced as the outcome of Mr. Raitt's work at the Allahabad Exhibition and at Dehra Dun. For the rest, the grass variously known as *sabai, baib* or *bhabar* (*Ischaemum augustifolium*), with a stiffening of imported chemical wood pulp, continued to be the staple material used for better class papers in the Titaghur, Bengal and Lucknow Mills; and cotton rags with a yet larger admixture of wood pulp made the Poona paper: the lower classes in all the mills being composed of waste paper, grass, jute and hemp waste, with a liberal dose of china clay to fill up the cracks. Capital was shy of pre-war prospects in the Indian paper trade.

Effects of the war and future prospects.

With the progress of the war, the consequent difficulties of obtaining wood pulp from Europe drove the Indian mills to the increased use of *sabai* grass, and simultaneously directed yet more attention to the other available raw materials; whilst the higher prices obtained for their products enabled the principal Indian companies to make provision for extensive refitting of their mills, so that after the war they might be better qualified to meet renewed competition with European makers, as well as the competition with America and Japan, which has grown since the war began. But even when the Indian Paper Mills are fitted with up-to-date machinery, economical power, and all available means of utilising waste products, much will seem to depend upon the extent to which associated industries are developed in India. Whatever raw materials may be used—whether grass or wood or rags—they all require to be chemically treated before they can produce paper. Up to now, bleaching powder, caustic soda, rosin for sizing, china clay and aluminoferric have all been imported, as have been also the colours used for toning white papers and dyeing coloured papers. Of late years, some use has been made of the rosin produced at the Government distilleries, and there are now prospects of china clay being produced on a commercial scale in India. The use of the electrolytic method of bleaching is also practicable. With a wealth of fibres to draw upon and with an adequate local supply of chemicals at a reasonable price, India certainly ought to be in a position not only to produce the whole of her own requirements of ordinary paper, but also to become one of the great pulp exporters. That some measure of protection would be required until these nascent industrial

developments attained strength is probable; but whether that protection will be forthcoming is a matter on which I am not in a position to speak.

Special kinds of paper.

The war has stimulated the manufacture of certain descriptions of paper formerly imported. For example, the thin bank paper used for typewriting is now produced by both the Titaghur and Bengal Mills. So is the soft-sized impression paper for use with duplicating machines. Medical anxieties for the soldiers' health led to enquiries as to the production of special latrine paper in India. This is elsewhere a specialised manufacture, and no facilities exist for the production of an article exactly similar to that commonly used in Europe and America. But a thin *badami* paper is expected to serve the same purpose, and large quantities of this are being made in Indian mills.

Wax paper is another special line, outside the activities of the ordinary paper mill. Urgent demands for increased supplies of this class of paper resulted in the production of a quite satisfactory sample by an Indian firm in Calcutta, and extensive orders have been placed with them.

I have not yet found it possible to obtain a satisfactory carbon paper of Indian make. From time to time, specimens which promise well have been submitted to me by Indian firms, but in every case it has been found that bulk supplies are oily, badly coated and exceedingly "messy." There is a good opening for a paper of suitable quality at a reasonable price, and I understand that a European firm in Calcutta has plans on foot for producing it.

Difficulties in regard to paper in England threatened to interfere with the supply of postcards to India. Thereupon the Indian mills produced a suitable board, and arrangements were made for printing the cards at the Government Press. No less than sixty-three millions of these cards have been provided for.

Pasteboard, strawboard, etc.

Though an advance has been made in the output of manufactured stationery writing paper, envelopes, etc.,—it is probable that for some years to come the finer qualities of writing papers, and special drawing and printing papers, will continue to be imported. But there are other directions in which openings offer for the further development of the Indian paper-making trade. Large quantities of strawboards, used for book binding, were formerly imported from

Holland and other European countries. Since the war, trade with Japan in this commodity has vastly increased, and I have had to place the whole of my demands on Government account in that country. There is no real reason why the boards should not be made in India. Some years ago—in 1906—a company for the manufacture of boards was started under the management of Messrs. F. W. Heilgers and Co., who also manage the Titaghur Paper Mills. Machinery was installed, and the sample boards produced gave good promise. But it would seem that appliances which gave good results in Europe required to be supplemented in India under different climatic conditions, and specially in he humid atmosphere of Calcutta in the rains. At all events, the working of the new factory did not prove a success. In the then condition of the paper-making trade, as a whole, there was no inclination to throw good money after bad in further experiment: the mill shut down in 1910, and the company liquidated.

Paste or pulp board for the manufacture of railway tickets and other like purposes is another fertile field now lying fallow. The making of pasteboards, with a stiff inner sheet and thinner paper pasted by hand on either side, is an old and well tried method. Formerly, large quantities of such pasteboards were bought by the Stationery Office for making labels for goods wagons, but for some years now they have been displaced by pulp boards, made in the Indian mills. These are in reality only a specially stout paper, made on the ordinary paper-making machine. They appear to be insufficiently stiff and insufficiently regular in make to suit the requirements of the railway ticket-printing machines, and it is understood that the North Western Railway Press is now again making ordinary pasteboards for railway tickets. There are, however, prospects of the production in India of strawboards and machine-made pasteboard of European quality at a comparatively early date, when these make-shift hand-made pasteboards will probably follow hand-made paper into desuetude.

There is just one other point that deserves mention before this brief sketch closes. Before the war, the selling price of Indian-made papers was controlled solely by the price at which imported papers could be sold. Since the war, comment has been made upon the fact that the Indian paper mills have made large profits. It is the fact that they have done so; but it is equally the fact that most of the ordinary sorts of paper in England have cost consumers from

half as much again to double the price at which they have been procurable in India. By the aid of the Indian mills, the armies in India, in Mesopotamia, and to some extent in Egypt have been kept supplied with paper and forms; the wants of the civil administration in India and in some of the further East colonies have been met; and, though the private purchaser in this country has had his difficulties, all essential publications have been maintained without break.

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The Paint and Allied Industries in India.

By N. Brodie,
Chemist, Government Test House, Alipur.

Composition of paint.

The usefulness of paint when applied to structures depends on the oxidation of linseed oil, when exposed to the air in thin films, to an elastic coat, which, reinforced by appropriate finely divided solids, known as pigments, forms a valuable protective, and incidentally decorative, covering. The mixture of pigment, and linseed oil in the best proportions, being usually too thick for application, is diluted with volatile liquids, such as turpentine, known as "thinners." A varnish contains no pigment, and the necessary strengthening of the film is attained by the incorporation of hard resins, usually copals. A varnish film is thus not only transparent but hard and lustrous.

The manufacture of paint, varnish and painters' materials, *viz.*, the necessary pigments, oil and thinners, forms an important group of industries. Some of these are entirely unrepresented in India, some are in a more or less experimental stage, while others are well established. Probably none, however, has reached the development that the country's resources justify and which may be anticipated in the future.

Unfortunately, no figures are available for the value of Indian manufactures. The values of general imports of paint and painters' materials during the last five years were as follows :—

Imports of paints and painters' materials into India from 1913 to 1918.

Year.	Value.
	£
1913-14	548,869
1914-15	503,051
1915-16	541,116
1916-17	765,346
1917-18	644,854

The recent increase in the value of imports is due to greatly enhanced prices, as the quantities imported are much less than in pre-war times. For example, the average price of red and white lead, which are grouped together for statistical purposes, has risen from about £24 per ton in 1913-14 to £65 in 1917-18. The imports include, besides those materials which have not so far successfully been manufactured in India, many which are made in the country. They also include large quantities of ready-made paints, most of which could more advantageously be made in India.

Raw materials : oil.

It will be convenient to consider first the position of India with regard to paint materials. The most important of these is linseed oil, which is used in paint making as "raw," "refined" or "boiled" oil. The raw oil is obtained by pressing flax seed, which is grown in several parts of India. A large proportion of the seed is exported to Europe and pressed there, the residue or "cake" being sold as cattle food. The cake amounts to over seventy per cent. of the original seed and, as there is little sale for it in India and it must therefore be shipped to Europe if it is to find a market, the advantage that the Indian manufacturer would otherwise have is naturally diminished. Nevertheless, a very flourishing oil-pressing trade has grown up, as have also the more technically difficult operations of refining and boiling. Refined oil is a partially bleached oil, which is used in white paint, and is usually prepared by treating raw oil with sulphuric acid. Boiled oil is prepared by heating raw or refined oil with small quantities of "driers," usually lead and manganese compounds, whereby it becomes not only much more rapid in drying but gives a harder film.

Indian raw oil is generally of good quality and is probably on the average better than imported oil. The quality of boiled oil is, however, a more important matter and this is rather variable. That of the best makers compares favourably with imported oil, but there is also much inferior oil on the market. On the whole, however, the industry may be considered to be in a satisfactory condition and there is certainly no need to use imported oil.

Turpentine.

Turpentine is obtained by the distillation of the resinous substance exuded by certain kinds of pine, the residue being rosin. The turpentine of different countries varies according to the species of pine from which it is produced, and Indian turpentine cannot be considered to be quite

as good as American, which is the most important variety. First-grade Indian turpentine, which forms much the greatest portion of the output, appears, however, to be suitable for paint and varnish making. The lower grades have their uses but are unsuitable for general purposes. Their indiscriminate employment has probably earned for Indian turpentine a reputation below its merits.

The turpentine industry * in India is of quite recent origin. In 1900-01 the production was only 1,600 gallons increasing to 29,900 gallons in 1910 and about 120,000 gallons in 1916-17. The unexploited sources of turpentine in India are considerable and, as the production in other countries seems to be increasingly incapable of meeting the demand, India may eventually become an exporting country. At present, however, the production does not equal the demand and no doubt importation will be necessary for some time to come. The increasing use of turpentine substitutes may help towards a better balance between production and consumption.

Turpentine substitutes are generally petroleum distillates with a range of distillation approximating to that of turpentine. It may completely replace turpentine in ordinary paint, but in the manufacture of varnish it must be mixed with real turpentine. Several brands are made in India and the output could doubtless be increased indefinitely to meet the demand.

Pigments.

The natural pigments found in India are barytes, ochres and certain kinds of red oxide; also a few minerals, such as china clay, which are occasionally used in paint, and gypsum, the use of which is rather undesirable than uncommon. Many other minerals have been suggested and sometimes used locally as pigments, but they are generally ill adapted to the purpose and make very poor paints.

Barytes, which is found in the Madras Presidency, Rajputana, Chota Nagpur and the Central Provinces, is the natural form of barium sulphate. It is a white, transparent substance characterised by its unalterability. It is used not only in white paint, to which in moderate quantities it gives increased permanence, but as the base of many coloured paints. As it is, at least according to English practice, a constituent, often a very large constituent, of most paints, its occurrence in India is a matter of some importance.

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* See page 376

Yellow and red ochres of good quality are found in the Katni district. Inferior ochres and certain kinds of red oxide occur in various parts of India. The Indian red oxides that have so far been found are, although quite good in other respects, of poor colour and therefore of limited usefulness. The best natural red oxide comes from the Persian Gulf and is imported in its crude state into India. This importation will probably continue, until artificial red oxide, which is a by-product of several industries, is produced in India.

The various deposits of ochres, red oxides and other ferruginous minerals have received more attention than their importance merits. The demand for ochres is not very large and some quite good mines appear to be unworked. The value of these materials in their crude state is small, and the greater part of their cost is due to the expense of the grinding and levigating required to reduce them to the necessary degree of fineness. Many country products, popular as substitutes for more conventional pigments because of their cheapness, are cheap merely because this treatment has been omitted, and they are used in such a coarse state that they necessarily produce poor paint. They are frequently so hard that proper grinding and levigating would cause them to be much more expensive than the pigments they are supposed to replace. Sometimes their chemical composition is such that good results cannot be expected, and frequently they are of poor colour or lacking in capacity. The immediate need, therefore, is not the discovery of fresh deposits, still less experimenting with new materials, but more machinery and skilled labour to utilize present resources.

Sienna and umber are not found in India, but these pigments although useful are not required in large quantities, and their absence is not a matter of importance. It is more to be regretted that no chalk deposits suitable for making whiting appear to be known.

The most important of the artificial pigments is white lead.* This has so far not been manufactured in India, although the feasibility of making it has frequently been considered. Attempts to make red lead have, however, been successful and a good quality, probably better than the average of the red lead previously imported, has recently been placed on the market. As the only material

* See page 113.

required for the manufacture of red lead is metallic lead, which is produced in Burma, there seems no reason why India should not, after a time, be independent of imported red lead. Another lead pigment, which might be made in India, or, more probably, Burma, is the so-called "sublimed white lead." This comparatively new pigment is essentially basic lead sulphate, real white lead being basic lead carbonate. It is prepared directly from galena (natural lead sulphide) by the volatilisation and oxidation of the ore. It is therefore a cheap pigment, and, as it has proved very successful in America, its manufacture here is worth consideration. It has, however, so far not been given a proper trial under Indian conditions and therefore only a tentative suggestion as to its manufacture can legitimately be made.

The manufacture of zinc white (zinc oxide) has been considered, but, as it is made by the direct oxidation of metallic zinc, it is usually manufactured in zinc-producing countries. Its manufacture in India from imported zinc appears to offer little advantage, but as the refining of zinc concentrates from Burma is likely to be developed in the near future, the manufacture of this and other zinc pigments may become possible.

The various lead chromes, which are yellow and orange pigments, are all made in India, as is Prussian blue and also, naturally, the mixtures of chromes and Prussian blue that form the important Brunswick and chrome greens. Chromium oxide green (which is quite different from chrome green) is also made. In these cases, imported chemicals are usually used, but no doubt this will be amended in the future. Of other pigments, lamp black may shortly be made in India, but there seems little prospect of the manufacture of ultra-marine. Some pigments of minor importance could readily be manufactured in India, were the demand sufficient.

Prospects of manufacture in India.

It will be seen from this summary that Indian products include all that is necessary for the vehicles of ordinary paints, while mineral resources and established manufactures[1] provide all the pigments necessary for some few paints and a large proportion of the pigments in other cases. Those pigments which seen unlikely to be made in India are, by reason of their comparatively small consumption, of no great importance and, if the projected new manufactures, particularly that of white lead, come into successful

operation, India can become almost independent of imported materials. Even in the event of our reverting as regards paint materials to pre-war conditions, our dependence on imports is probably less than is the case with British manufacturers. and the balance of advantage is decidedly in favour of making the majority of paints in India. The importance of studying local conditions and the convenience of ready communication between manufacturers and consumers cannot be ignored and, other things being equal, it is for these reasons of the greatest advantage that paints, except of the simplest character, should be made in the country in which they are to be used.

The actual process of paint making calls for little comment. In principle, it is merely the thorough grinding and incorporation of the pigments with oil and the subsequent mixing of the stiff paint so produced with the necessary oil and thinners. Its successful operation is a matter of adequate machinery and skilled labour. Unfortunately, it cannot be said that all Indian factories fulfil these conditions, and some appear consistently to turn out poor paint. The unfavourable impression naturally produced has undoubtedly re-acted on those whose products are satisfactory and, in some cases, has caused it to be thought that good paint cannot be produced in India. It, however, hardly affects the general question and those who are prepared to take proper precautions in buying and to pay a reasonable price can, in normal times, get what they want; while, under war conditions, the best Indian-made paint has shown a marked superiority over that imported. This is largely due to the exceptionally favourable position as regards supplies of linseed oil.

Varnish.

Copal varnish is the most important kind of varnish and is sold under such names as "copal," "body," "carriage," "oak," etc., varnishes. Gold size is also a variety of copal varnish. Copal is a general term covering the majority of the hard varnish-making resins. The grading is complicated but the best, that is the hardest, varieties come from Africa. Most of the varnish sold in India is made from copal imported from Singapore. This is one of the softer resins and gives a varnish of medium quality. Varnish usually contains about 20 per cent. of copal, the other materials being linseed oil, turpentine and turpentine substitute.

As the latter are all obtained in India the position is exceptionally favourable, particularly compared with that of the English makers, who have to import all their materials. The plant required could readily be produced and the general principle of varnish making is simple; nevertheless, considerable difficulties are to be expected in any attempt to make high-class varnish, such as would satisfy the railways. The method of varnish making, in outline, consists of melting the copal and afterwards adding the linseed oil and driers. When solution is complete, the mixture is allowed to cool and the thinners added cautiously during the cooling. The actual details of the operations are entirely a matter of prolonged practical experience, and the manipulation of varnish necessitates a proper supply of skilled labour. It will be a matter for regret if the industry does not become established in India, but it is not one to be undertaken lightly.

Cheap varnishes are made largely from rosin and range from a simple solution of the rosin in a petroleum distillate to complex mixtures containing tung oil, etc. The simpler rosin varnishes are made in India, and some of them have a legitimate application for certain special purposes. The comparatively modern tung oil preparations which, as far as is known, are not made in India, are the best rosin varnishes for general use. They are not, however, an adequate substitute for copal varnish and stand exposure poorly.

Spirit varnishes made from shellac include "shellac varnish," "knotting," "French polish," etc. They are essentially solutions of shellac in spirit and therefore, as India is the principal shellac producing country, can advantageously be made in the country. Lacquers are also varieties of shellac varnish but appear to be usually imported, although there is apparently no essential reason why they should not be made in India.

The Manufacture of Glass in India.

BY ALFRED CHATTERTON, F.C.G.I., C.I.E.

History.

The art of glass making reached a high degree of perfection in the times of the early Roman Emperors; but no equivalent simultaneous development has been traced in India, although what he terms 'Indian glass' is mentioned by Pliny as being of superior quality, which he attributes to its manufacture from crystals. Archæological explorations in India, have resulted in the discovery of a number of small glass vessels; but such relics are crude specimens of a very primitive industry. Whether they were made near the sites in which they have been found or whether they were brought from a distance, is not known. No traces survive of an ancient Indian glass industry in India, and all that is certain is that in the sixteenth century it existed as an established industry which had not advanced beyond the stage of producing a very inferior material, utilised almost entirely for the manufacture of bangles and, to a very limited extent, for small bottles to hold perfumes and for flasks in which to store Ganges water. The demand for glass bangles was, and still is, almost universal, and the industry was carried on in many places; but nowhere did it rise above the dead-level of inferiority just described.

Buchanan, in his journey from Madras through Mysore at the beginning of the nineteenth century, in reference to the industry at Muteodu, graphically depicts the state reached in the art of glass making at that time. After describing the processes employed and the results obtained, he says, "The glass maker's furnace here is rather better than that of Chenna-pattana; but still it is extremely crude. The manufacturers say that when the army of Lord

Cornwallis left Seringapatam, they gathered with much pains a number of broken bottles, which they found where he had encamped. These they thought a treasure; but, after having been at the expense of bringing the bottles to Muteodu, they found that their furnace was not sufficiently strong to liquify European glass. The bottles were then reduced to powder and mixed with alkali, but these materials produced only a useless white mass. Our glass, therefore, is considered by them as useless as our cast iron; for neither of these substances are in a state upon which the fires of the natives have any effect."

Modern manufacture.

The manufacture of glass and glass articles in modern factories in India is only a quarter of a century old. Between 1892 and 1900, five glass factories were established, of which two were Indian concerns which did not long survive. The remaining three were under European management assisted by men brought out from glass works in Europe, and two of the factories were well equipped with large modern smelting furnaces and plant and are believed to have been amply supplied with capital. The first, established about 1892, closed in 1899; the second, worked from 1898 to 1902, and the third opened in 1900 and failed in 1908. A final effort on the part of Europeans was made in Madras in 1909; but after about three years' work, the company was compelled to cease operations and finally went into voluntary liquidation. The industry seems to have had a peculiar fascination for Indians, who undeterred by the failures of comparatively large concerns run by Europeans, started 16 glass factories on a smaller scale between the years 1906 and 1913. In some instances, they obtained assistance from the European trained glass workers who elected to remain in the country after the failures of the earlier ventures; in others, they relied upon Japanese glass workers under the control of Indians who had been to Japan to learn the trade. The experience available from the failures which had already occurred does not seem to have been made much use of, and in no case were thorough preliminary investigations made, such as we now deem essential, if any new industry were to be started in this country. The result was that, at the outbreak of war, only three of these factories were in operation and none of them was making a commercial profit, though the Talegaon factory, under the aid of the Paisa Fund, was paying

its way on the somewhat peculiar and non-commercial lines on which it was run.

Present position : the bangle industry.

Recent enquiries show that there are now in India about 20 glass factories at work. Of these, 7 are situated at Firozabad and are entirely engaged in the manufacture of *chouri* glass, which is purchased and remelted by bangle makers in both the United Provinces and the Punjab. Formerly, the glass for the bangles was made from indigenous materials gathered more or less in the locality: but in recent years, since the manufacture of *chouri* glass was started at Rajpur, the use of local materials has been given up and the glass is now made with imported soda, with lime from Katni and with sand from the country to the south of Allahabad. The coal, of course, comes from Bengal. Firozabad thus possesses no natural advantages for the manufacture of glass, and the trade flourishes there almost entirely because of the large colony of glass bangle makers. The factories devoted to the production of *chouri* glass are in the hands of Hindu capitalists, who are stated to have invested roughly about four lakhs of rupees in the industry, and the outturn of glass is estimated at between 20 and 30 tons a day. The largest glass works in the town are just outside the railway station, and here the proprietors have installed a gas-heated furnace of quite a modern type. The glass manufactured is very soft, obtained by the use of a considerable proportion of alkali. This is necessary because the bangle makers work at a comparatively low temperature and would be unable to deal with hard glass. For this reason, apparently, cullet or broken glass is not employed. The output of the furnace is about four tons of glass a day and the proprietors state that last year their gross outturn was about 900 tons. The glass is prepared in a great variety of colours, and the demand is so considerable that the plant has recently been duplicated. There are between 50 and 60 factories in Firozabad where bangles are made. The bangle makers work in gangs of from 12 to 20 round a central furnace fired with wood. The furnace is cheaply constructed of mud and the temperature is not very high. Each bangle maker has an assistant, and as yet no improvements have been introduced into their methods of working. A Parsee firm established in Firozabad have, however, since the outbreak of war made considerable strides in the manufacture of bangles in imitation of those formerly

imported from Austria. They have discovered that suitable glazing materials can be obtained from England, and after a number of experiments have succeeded in constructing a muffle in which these glazes can be successfully melted on to the bangles. The industry at the present time is in a very flourishing state and is in the hands of enterprising intelligent men, who are willing to adopt any suggestions that seem to be practicable. It represents a turn-over of at least 20 lakhs of rupees a year and probably supplies one-third of the Indian demand for bangles. The Firozabad industry is undoubtedly the best established branch of the Indian glass trade; but whether this satisfactory state of things will continue in peace time, will largely depend upon the education of the bangle makers and the improvement of their productions.

Other forms of manufacture.

In his notes on the industries of the United Provinces published in 1908, Mr. A. C. Chatterjee furnishes an interesting account of the state of the glass industry at that time and, comparing the state of things as described by him with the present condition of the industry, it is evident that substantial progress has been made during the last ten years. Although plate and window glass, pressed glass, optical glass, soda-water bottles and, with the exception of a few rough tumblers, table glass are not yet made in India, direct enquiries have established the fact that there are now 12 glass works engaged mainly in the production of lampware and, to a less extent, of bottles and carboys. Stimulated by the demands for specialised forms of glass passing through the Indian Munitions Board, several factories have, with some degree of success, turned out glass tubing, flasks, beakers, petri dishes and test tubes of non-resistant glass, and one or two small concerns have been started to work up glass produced elsewhere to meet the demands of the scientific laboratories controlled by the Indian Medical Service. Apart from the bangle trade, the capital invested in the glass works now running is probably not less than 15 lakhs of rupees: but it is very difficult to frame even an approximate estimate as to the value of the monthly outturn. The majority of the factories have been recently started and their record so far is, in most cases, a continuous struggle against difficulties, due partly to inexperienced control and lack of trained labour and partly to short supplies, at very high rates, of essential raw materials such as soda and coal.

The demand for glass in India is, to some extent, indicated by the value of the imports which are classified under the following heads :—

TABLE 1.—*Imports of glass into India.*

Articles.	Value (in lakhs of rupees).		
	1913-14	1916-17	1917-18
	Rs.	Rs.	Rs.
Bangles	80	43	35
Beads and false pearls	24	21	24
Sheet and plate glass	22	28	23
Lampware	17	11	18
Bottles and phials	14	16	37
Sodawater bottles	6	9	
Tableware	8	7	10
Miscellaneous	10	15	15
TOTAL	190	150	162

Deductions regarding the effect of the war can only be drawn from this table if it is remembered that values have increased enormously and that current prices have been nearly doubled. The imports of bangles have very greatly decreased in value and still more in volume. The value of imported lampware is practically unchanged, but the quantity has decreased by probably 50 per cent. The reduction in the consumption of kerosine oil has not been on a corresponding scale, and, as the imported glass from Japan is of very inferior quality, it will be approximately accurate to assume that nearly half the requirements of the consumers have been met by the Indian glass works. On general grounds, therefore, we may assume that the value of the outturn of glassware by organised factories in India is, at the present time, not far short of 20 lakhs of rupees a year and, if to this we add the value already arrived at of the bangle glass trade at Firozabad, we arrive at a minimum total of 40 lakhs a year.

Prospects of the industry.

The general conditions under which the glass industry in India has hitherto worked are described in Appendix E of the Report of the Indian Industrial Commission, which clearly shows that, if the industry is to flourish in India, the haphazard methods of the past must be abandoned and the industry developed on scientific lines. As we have seen, the industry has reached considerable dimensions under the stress of war conditions; but as these will now gradually pass away, there is bound to be a severe set-back unless, during the transition period, efforts are made to improve matters. In the words of the Indian Industrial Commission, "The glass industry, even in its simplest form, is highly technical and can be efficiently carried on only by scientifically trained managers and expert workmen. The present stage has been reached by importing men, only partially equipped with the necessary qualifications, from Europe and Japan and by sending Indian students abroad to pick up what knowledge they can. The glass industry is a closed trade and its secrets are carefully guarded, so that the latter method has not proved conspicuously successful." It is now urgently necessary that the industry should be assisted by competent experts, and the problem which the Government of India will have to face, if the recommendations of the Indian Industrial Commission are accepted, is how to set about the task with the least possible interference with the vested interests which have grown up and which undoubtedly deserve consideration.

It is difficult to assign adequate reasons for the location of most of the factories in the places where they have been started. The personal element was probably the determining factor and, under peace conditions, some of the factories will find themselves very severely handicapped by the great distances which separates them from the sources whence they derive their raw materials, especially when there is no compensating proximity to markets for the finished goods. Naturally, the cry for protection after the war has been strongly raised; but it should be pointed out that this will not help existing factories if the industry is, in the future, developed on sound principles. We may assume that it only requires the application of what are now well-proved methods to the problem of establishing the glass industry in India, and the result will be the establishment of new works which will prove even more formidable competitors than foreign factories situated in Europe or Japan.

It therefore seems to be inevitable that most of the existing works will be unable to continue working and it will be their fate to succumb either to external or to internal competition. These facts are fully recognised by the managers and proprietors of existing glass factories, and, almost without exception, they propose that the initial errors they have committed in selecting sites for their factories should be minimised by special concessions for the transport of raw materials and manufactured articles over the railways. There are, no doubt, anomalies in regard to the railway rates and they have been brought prominently to light; but in the economics of the industry, they play an extremely unimportant part and they should not be allowed to obscure altogether the main issue, which centres round the fact that the sites for most factories have initially been selected regardless of the fact that the assemblage of the raw materials would involve heavy transport charges.

Furnace difficulties.

Leaving for the present the difficulties which the proprietors and managers of glass factories have created for themselves by their total disregard of transport questions, we may turn to the consideration of the most urgent problems requiring technical investigation in the immediate future. These relate to the design and construction of furnaces and the manufacture of crucibles and pots. Every glass factory in India depends upon Jubbulpore for firebricks and fireclay, and most of them obtain their crucibles and melting pots from Japan, though attempts have been made, but with a very limited degree of success, to prepare them locally. The majority of the furnaces are built after the pattern introduced by the Japanese workers and are open-fired. Either because the design is faulty or because the materials used are of inferior quality, these furnaces last only a few months. They are extraordinarily extravagant in fuel, and most of the factory managers admit the consumption of from 2 to as much as 4 tons of coal per ton of glass melted. In some cases, regenerative gas-fired furnaces are in use and in one or two instances the glass is melted in tanks. These latter are comparatively economical; but owing to imperfections, both in the design and in the materials of which they are constructed, they have not fully come up to expectations.

It scarcely seems open to doubt that in attempting to help the Indian glass industry, the first step should be to deal with these

matters. Designs for furnaces of different types can be easily procured; but considerable expert knowledge and local experience is necessary to decide between the claims of conflicting methods of preparing glass for a specific purpose. A more difficult matter, however, is the provision of suitable fire-resisting materials. Much valuable work in this direction has been done for the iron and steel industry and the results obtained should be of some use to glass makers. No one in India has succeeded in making crucibles, and it is not yet clearly established whether this is due to the defects in the material employed or to lack of experience in manipulating it. Before the war, crucibles were chiefly obtained from Japan and the average price paid for them was Rs. 20 each. Now they cost Rs. 80 each and the glass makers are, in most cases, making energetic but futile efforts to render themselves independent of Japan.

It is not easy to arrive at an accurate estimate of the cost of making glass, even when such accounts as are usually kept are available for examination; but a comparison between the value of the outturn on a good working day with the value of the outturn in the course of a year reveals an appalling degree of inefficiency, almost entirely attributable to furnace defects. Experts to deal with these problems should, therefore, be engaged.

From information furnished by the manufacturers of glass in India, the following table, showing the composition of glass mixtures used in India, has been prepared.

TABLE 2.—*Various glass mixtures used in India.*

Material.	1	2	3	4	5	6	7	8	9
Sand . . .	100	100	100	100	100	100	100	100	100
Soda . . .	40	50	40	42	50	43	33	48½	53
Lime . . .	10	10	12	20	15	8	16	10	12½
Saltpetre . .	...	...	2	...	4	11½	2	6	10½
Cullet . . .	...	...	...	...	50	195	...	...	...

Other items occasionally used such as manganese, red lead, arsenic and borax are omitted, the quantities involved being very small.

Raw materials.

Except in two instances, where cullet is employed, the glass is invariably composed of sand, soda ash and lime with, in some instances, a rather considerable percentage of potassium nitrate. The high percentage of soda ash makes the glass expensive, since this chemical must be imported from abroad; but it renders the glass easily fusible and therefore suited to the inferior refractory materials employed in the furnaces. Although sand suitable for glass making has been found at a number of places, for reasons not very apparent, all the glass factories in India, with but two exceptions, rely upon the crushed sandstone from the hills south of Allahabad at Loghra and Bargarh. The sources of supply of lime are more widely distributed; but the soda ash hitherto used has invariably been imported and is usually supplied by Messrs. Brunner Mond & Co. In addition to the raw materials, which actually form part of the finished product, the fuel used in melting them is an important item and bulks very largely in the cost of making glass. Except in one or two instances where wood is used, the fuel comes from the Bengal coalfields and the cost increases with the distance it has to be hauled to the factory. The largest, and apparently the most successful, glass works in India is situated at Naini, a few miles from Allahabad and close to the sand stones of Loghra. It may be interesting to compare the prices paid for raw materials at this factory with those paid by a recently established concern in Bombay. At Naini, sand costs four annas a maund as compared with fifteen annas in Bombay; lime at Naini is Re. 1 per maund as compared with Rs. 2 in Bombay; soda ash at Naini is Rs. 9-6-0 per cwt. as compared with Rs. 9 in Bombay, whilst coal is Rs. 13 a ton at Naini as compared with Rs. 24 in Bombay. Add to these disadvantages in respect of the cost of procuring raw materials, the additional fact that the Bombay factory is fully exposed to the competition of imported glass, while the Naini factory is protected in the markets of Northern India by a railway lead of several hundred miles, and it is obvious therefore that the latter enjoys enormous advantages due to its location.

The two most important items in the cost of making glass in India are (1) coal and (2) soda ash. The coal is cheaper the nearer it is used to the mines from which it is obtained. Other things being equal, then, a glass factory stands a better chance of surviving when it is situated near a coalfield. With gas-fired furnaces, the

quality of coal is not of so great an importance as is generally assumed to be the case. Instead of soda ash, which is anhydrous carbonate of soda, sulphate of soda is largely used in Europe in the manufacture of glass; but to obtain the same result, approximately 40 per cent. more sulphate of soda than carbonate of soda must be used, and further, a batch containing sulphate of soda requires a higher temperature to produce the necessary reactions to form silicate of soda. Whether under these conditions, indigenous sulphate of soda can compete with soda ash is not known. A cheaper source of soda is, however, a matter of such great importance that attention may be seriously directed to the *usar* soils of Northern India which contain both the carbonate and the sulphate. In the past, they were the basis of the indigenous glass industry, and it is possible that investigation may bring to light deposits sufficiently rich to make it worth while extracting the salt and refining it. The most probable direction to which the Indian glass maker may look for a cheaper source of alkali is the soda deposits at Magadi in British East Africa. Magadi lies about 60 miles to the south of Nairobi and 370 miles from Mombassa. Now that the war is over, there should be no great delay in completing the railway communication between Magadi and the sea, and competition between soda ash and Magadi soda should materially benefit the Indian glass industry (see also page 70).

The next question for consideration in dealing with the problem of the improvement of the glass industry, is how to provide for the training of glass technologists. At present, as we have seen, the glass manufacturer in India is confined to the production of a very soft soda glass, only suited for a limited range of wares, and it is obviously necessary to expand the basis of the industry by the production, as soon as possible, of higher qualities of glass suited for a wider range of articles. There is an immense market in India for sheet and plate glass and even a larger market for bottles and phials. The former is as yet unexploited, while the manufacture of bottles has only just been commenced and no soda-water bottles have been made. As soon as the difficulties connected with the furnace materials have been satisfactorily solved, the experience gained with the glass industry up to the present time seems clearly to indicate that there are good prospects for further developments, provided that the details are worked out by competent experts and that, at the outset, skilled workers are freely imported to train Indian labour.

Labour difficulties.

It is true that a considerable number of men have been trained, in the last few years, by the Austrians and Japanese who were brought out to India in connection with the pioneer efforts, to which reference has already been made. Useful work has been done by the Paisa Fund at the Talegaon Glass Works in training glass blowers, and the expansion of the industry under war conditions is chiefly due to the supply of men who have come from this place; but the men are not well-trained and the inferior quality of Indian glassware is partly due to this fact. There are, however, signs of progress under the pressure of war demands, and this is satisfactory as furnishing evidence that a well-devised scheme for the training of glass workers will meet with success.

During the war, it was easier to find capital than labour, and the managers of every factory have complained of the shortage of skilled men and the difficulty in training fresh hands. At present the glass blower dominates the situation and, though he earns very high wages, there is much friction between the managers and the men. The glass industry has come to stay; but without aid from the State, it is likely to make very slow progress in the future. Adequate arrangements are necessary to provide for the thorough training of glass blowers and men to work glass-blowing machinery. Operations need not be on an extensive scale; but the technical staff should, at the beginning, be much larger than would be justified by ordinary commercial considerations. So much of the work will be of an experimental character, the results of which should be placed at the disposal of those already engaged in the industry, that a subsidy to a private factory will hardly meet the case, and it seems desirable that the next step in developing the glass industry should be taken by Government and should consist in establishing a glass factory equipped with an efficient technological laboratory and provided with a competent staff of experts and skilled glass workers.

It might, at first sight, seem possible to make a considerable advance in the technology of glass in India by utilising existing glass works for practical experiments; but it is almost certain that none of them are really in a position to do such work, and that such a method will cause inordinate delay. A Government glass factory is, therefore, essential: but it should only be started after the problems to be dealt with in India have been examined by a man in the glass trade, whose technical knowledge, experience and

breadth of outlook will be sufficient to enable him to indicate generally the steps which must be taken to establish the industry on a firm footing. The technological aspects are not dissimilar to those which will have to be encountered in establishing any chemical or metallurgical venture; but the training of the workmen is a very special problem, for the solution of which the experience of the past is not likely to afford much useful guidance.

The question of the transport of raw materials to the glass factories has already been discussed. There remains the question of packing and transport of finished articles. The Indian Industrial Commission has made recommendations regarding railway administration to facilitate the future development of industries in India, and there is nothing in the glass industry which calls for exceptional treatment, unless it be that emphasis should be laid on the necessity for extra care in handling crates or cases containing glassware. It may also be urged that, as the ratio between the net weight and the gross weight of glass packed for transport is usually very low and as railway rates are charged on gross weights, a specially low classification may well be allowed to glass in transit. For the packing of glassware, the crates made from reeds grown in the bed of the Ganges are very satisfactory, and every facility should be given to enable glass factories to obtain supplies.

The economics of the glass industry have, as yet, been imperfectly studied and till more data are available, little that is likely to be useful can be said regarding the selection of sites for glass works. It should be noted that in the glass industry there is but little waste of the raw materials in the processes of manufacture, whilst a cheap supply of coal is undoubtedly an important factor. Ideal conditions for the manufacture of glass would be realised, if suitable sand could be found in proximity to the coalfields. It has been suggested that whilst glass is best made under such conditions, the glass blower may economically work in the neighbourhood of large markets for glass-ware, obtaining his glass from a large central factory and re-melting it in comparatively small furnaces. This is what the bangle makers now do. Attempts have been made to utilise electric furnaces for glass melting and apparently with some degree of success. The development of electric energy in India from water power may, in the future, possibly render it practicable to adopt the electric furnace to the glass blower's requirements; but at present, neither is the electric furnace sufficiently developed for use in India

nor is a sufficiently cheap supply of electricity available, and future lines of development must be framed on the assumption that, except in the neighbourhood of the coal mines, the cost of fuel will always be a heavy item in glass manufacture.

Cocoanut Industries of the West Coast of the Madras Presidency.

By C. A. Innes, I.C.S.,

Director of Industries, Madras.

In the year 1913-14, the year previous to the outbreak of war, the principal exports from the chief ports of the west coast of Southern India (Mangalore, Tellicherry, Calicut, Cochin and Alleppey) were the following :—

Table 1.—*Principal exports from west coast of Southern India in 1913-14.*

Article.	Value [thousands of rupees.]
	Rs.
Products of the cocoanut—	
(1) Copra	180,77
(2) Coir	103,48
(3) Coconnut oil	93,65
Total	377,90
Other products—	
(1) Coffee	152,28
(2) Tea	64,83
(3) Pepper	51,70
(4) Rubber	39,28
(5) Ginger	15,01
Total	323,10

Importance of the cocoanut.

Striking though these figures are, they do not bring into adequate relief the outstanding importance of the cocoanut as an economic factor on the west coast, and naturally they give little indication of the part played by the products of the palm in the domestic life of the people. It is probable that in recent years most of the available copra on the west coast has been exported either in the form of copra or in that of cocoanut oil. At any rate, in 1917 large quantities of copra were imported from Ceylon to supplement west coast supplies. It is also probable that a fair proportion of the available coir is exported in the form of yarn, matting or rope. But copra, cocoanut oil and coir do not exhaust the products of a tree, every part of which has its own definite use or uses. The leaves are used for hutting and roofing, and for the manufacture of brooms, baskets and umbrellas, or are burnt for manure. The shells are the fuel of the coast. The juice is drunk either fermented or unfermented and is made into jaggery and distilled into arrack. The nuts are eaten, the oil is used for lighting and in cooking, the trunks are employed in building or are used as water pipes. Along the littoral, moreover, almost the whole population is dependent on the cocoanut for its livelihood. The trees belong almost exclusively to small Indian cultivators. Thousands of boats ply on the creeks and backwaters which fringe the coast, taking coir, copra and cocoanuts to Cochin and other export centres. The majority of the male population earn their living by poling these boats or by tapping the trees for toddy, gathering the nuts, splitting the husks or preparing the copra. The women beat out the fibre and twist it into yarn. Coir yarn is to some extent the currency of the coast. Every evening one may see women carrying hanks of yarn to the nearest shopkeeper and exchanging them for rice, chillies, tobacco and other household necessaries.

Its cultivation.

It is impossible to give any accurate statistics of the area planted up with the cocoanut palm on the west coast. The crop is a permanent one, and no annual statistics of acreage are published by the Agricultural Department. It may safely be estimated, however, that on the west coast half a million acres are planted up with the tree, and that not less than 1,600 nuts per acre are a normal annual crop. The total annual crop, therefore, may be estimated at not less than 800 million nuts,

worth at pre-war prices nearly four crores of rupees. The tree can be grown inland up to an elevation of one thousand feet but flourishes best near the sea. The west coast consists of a long narrow strip of land which is almost entirely cut off from the east by the Western Ghats. The rainfall is extremely heavy and numerous streams and rivers flow down from these hills to the sea. Owing to their velocity, they carry with them enormous quantities of organic and vegetable matter, and as the results of this discharge over many hundreds of years, large low-lying strips of land have been gradually formed in the sea, and the lagoons and backwaters, which form an almost continuous waterway from Trevandrum in the south to Calicut in the north, have come into existence. It is along the shores of these lagoons and backwaters and along the banks of the rivers that the cocoanut flourishes best and yields most abundantly. The long line of backwaters moreover has only one important outlet to the sea, namely at Cochin, and British Cochin is accordingly the great market and port for all products of the cocoanut. In localities such as those mentioned the palm grows with extraordinary luxuriance, but the cultivation is admittedly inefficient. There are no large plantations under European management, and the industry is almost entirely in the hands of small Indian cultivators. Overplanting is the commonest defect, but no attention has yet been paid to the selection of seed nuts with the object of increasing the copra content. In well-organised estates in the Straits Settlements, 4,000 nuts are said to produce one ton of copra, but on the west coast on the average not less than 7,000 nuts are required to produce the same quantity. The Madras Agricultural Department has now taken up the study of the cocoanut and has opened four experimental stations where seed selection, methods of cultivation and other questions will be investigated.

Copra.

Before the war, the most important of the products of the cocoanut, from the point of view of foreign export trade, was copra, the dried kernel of the nut. The oil which is extracted from copra is used on a very large scale, mainly in the manufacture of edible oils and fats. The course and distribution of the copra trade are instructive and can best be exhibited by the following comparative statistics.

TABLE 2.—*Exports of copra and cocoanut oil (foreign trade) from the Madras Presidency*

Year.	COPRA.		COCOANUT OIL.	
	Quantity [thousands of cwts.]	Value [thousands of rupees.]	Quantity [thousands of gallons.]	Value [thousands of rupees.]
		Rs.		Rs.
1906-7	125	*18,76*	943	*13,86*
1907-8	118	*21,28*	1,138	*16,50*
1908-9	384	*52,52*	2,814	*39,72*
1909-10	532	*74,19*	2,408	*37,09*
1910-11	416	*78,26*	1,890	*33,06*
1911-12	632	*113,16*	2,121	*39,66*
1912-13	685	*128,30*	930	*18,43*
1913-14	762	*155,46*	1,080	*22,48*
1914-15	635	*122,97*	1,784	*35,96*
1915-16	312	*57,04*	2,016	*38,57*
1916-17	505	*94,26*	2,019	*42,53*
1917-18	107	*19,20*	2,490	*46,40*

It will be seen that while the export of copra steadily increased from 125,000 cwts. valued at Rs. 18·76 lakhs in 1906-7 to 762,000 cwts. valued at Rs. 155·46 lakhs in 1913-14, exports of cocoanut oil fluctuated and were no greater in 1912—14 than they had been in 1906—8. In the five years preceding the war, Germany took nearly 73 per cent. of the exports of copra from the west coast, but only 33 per cent. of the exports of cocoanut oil. The predominant position occupied by Germany in general and Hamburg in particular in the edible oil seeds trade before the war is well known, and many reasons for this predominance are given in the evidence presented to the "Committee on edible and oil producing nuts," which sat in the United Kingdom in 1915. It would take too long to deal with the matter in detail, but the broad fact appears to be that before the war vegetable oils were in far greater demand on the continent for edible purposes than in England. Germany had a further advantage in that there was a very large demand in the country for cocoanut oil cake for feeding stock, and an excellent system of inland waterways enabled this cake to be distributed cheaply. The trade in oil seeds, moreover, was carefully fostered by the admission of the raw material into Germany free of duty and by the imposition of a duty on cocoanut oil. At any rate, whatever

the cause, the fact remains that Hamburg was the most important market in the world for the oils and seeds required for the edible oil and fats industry, and that very numerous crushing mills were situated on the banks of the Elbe near the town. The copra was crushed in these mills, and while the cake remained in Germany, much of the oil was exported to Holland, for use in the margarine factories, and also to the United Kingdom. In 1913, for instance, no less than 30,236 metric tons of cocoanut oil were shipped from Hamburg to England. The sudden stoppage of exports of copra to Germany was a severe blow to the west coast, but it may be hoped that much of the trade with Germany has permanently been diverted to the United Kingdom. The war has greatly increased the use of margarine in the United Kingdom, and many factories for the production of edible oils and fats have come into existence. The immediate result of the war was not only a revival of the trade in cocoanut oil with the United Kingdom but also a large increase in the export of copra to the home country. The trade in copra has been checked by shortage of steamers in India and of man power at home, but copra is essential for the manufacture of high-class edible oils and fats, and when normal conditions are restored the United Kingdom will probably be an important customer for west coast copra. France, however, has taken the place of Germany as the principal buyer of copra, exports to that country having grown from 68,000 cwts. valued at Rs. 13·72 lakhs in 1913-14 to 419,000 cwts. valued at Rs. 77·99 lakhs in 1916-17.

Method of preparation.

Copra is the dried kernel of the cocoanut. The ripe nuts are collected every 40 or 45 days according to the season of the year and are husked by being struck on a sharp pointed stick fixed vertically in the ground. The husks are then carried away to the soaking pits, and the kernels which are still enclosed in hard shells are removed to the drying grounds. The shells are here held in the left hand and struck sharply across the centre with a knife, the operation dividing them into two halves each containing half the kernel. These halves are dried in the sun, and after two days' exposure the kernel shrinks and comes away easily from the shell. The kernel is dried in the sun for a further two or three days according to the weather and is then ready for sale as copra. It is important to avoid any damping of the kernel during the process of drying, as any moisture sets up mould and causes fungi to appear which reduces the value

of the copra. Nuts which are cut before they are thoroughly ripe are especially apt to become discoloured in this way. and no amount of drying will save them from becoming inferior copra. Malabar copra properly prepared is eminently suitable for edible purposes, and for years has stood at the top of the market. The following typical prices in Europe which are published in the book "*All About Coconuts*" illustrate this remark:—

TABLE 3.—*Prices of copra in 1912 and 1913.*

Place.	Prices per ton.					
	July 1912.			September 1913.		
	£	s.	d.	£	s.	d.
Malabar	27	10	0	32	10	0
Ceylon	26	12	6	32	0	0
Java	24	13	9	31	5	0
Straits	24	10	0	31	5	0
Manilla	23	8	9	30	10	0

In Ceylon, the copra is ordinarily grilled on a framework of trays constructed over a pit in which a fire is kindled with cocoanut shells. In other countries, it is dried in kilns or in more modern hot air rotary drying machines. It is believed that Mr. John Grieve, a Cochin merchant, experimented with kilns in Cochin many years ago, but the experiments were unsuccessful, and sun drying is the universal practice on the west coast. In most cocoanut countries the objection to sun drying is not only the loss of time involved, but also the fact that it is impossible to rely on brilliant sunshine during the whole period of preparation. This latter objection, however, does not apply for several months on the west coast since from December to the end of March hardly a drop of rain falls. It is true, however, that during the monsoon months very little copra can be prepared on the west coast, and probably one reason why artificial drying has never come into vogue on the west coast is that the copra industry is mainly in the hands of small merchants, who have no capital to invest in expensive drying machines. But many people ascribe the superiority of west coast copra mainly to the fact that it is sun dried, and in view of the fact that Malabar

copra not only commands a higher price than any other copra but is also most economically prepared, it is doubtful whether any advantage would be gained by resorting to artificial drying. For export purposes copra is sliced into small pieces and is shipped in bags each containing $1\frac{1}{4}$ cwts.

Cocoanut oil.

Copra is very rich in oil content. According to the book "*All About Cocoanuts,*" which has already been quoted, Malabar copra yields 68 per cent. of oil, Ceylon 65 per cent., while that from Manilla copra is as low as 59 per cent. Malabar oil, or to give it its trade name, Cochin oil, is the finest cocoanut oil in the world and at one time commanded a 35 per cent. premium over Ceylon oil. Even now it keeps its position, though with a smaller margin. Thus in April and May 1912 the following prices were quoted in Europe for Cochin and Ceylon oil respectively per ton :—

TABLE 4.—*Price of cocoanut oil in 1912.*

Quotation.	Cochin.			Ceylon.		
	£	*s.*	*d.*	£	*s.*	*d.*
April spot	46	0	0	41	10	0
April-May c. i. f.	48	15	0	41	0	0

The characteristic of the best Cochin oil is that it is colourless almost like water. Formerly the copra was pressed solely in country *chekkus* or oil mills, which consisted of a large wooden mortar firmly fixed in the ground and a corresponding pestle revolving inside it. The pestle was worked by a lever which a pair of bullocks carried round in a circle. Even now these primitive oil mills are still seen, and they are said to produce the best oil. But in Calicut, Cochin and Alleppey their place has been almost entirely taken by power mills driven by oil or steam. Most of these mills are known as "chuck" mills, chuck being a corruption of the Malayalam word *chekku* and, as their name implies, they are similar in principle to the country *chekku* with the exception that the mortar and not the pestle revolves. The chucks which are usually of cast iron and are made in local foundries, each require about 3 B. H. P. to drive and deal with about 50 lbs. of copra per hour, and mills of 15 and 20 chucks are not uncommon. One hydraulic

mill consisting of two cage presses exists at Cochin. In the chuck mill, the copra is sliced into small pieces and is then fed into the chucks. The oil as it is extracted runs out through a hole in the bottom of the chuck and is conducted by a trough or pipe to a barrel or other receptacle. The residue mixed with a little gum arabic is *poonac* or cocoanut cake, valuable both as a food-stuff for cattle and as manure. Before export to Europe, however, the oil is carefully filtered and otherwise treated in the yards of the shipping houses in Cochin. Most of the cake remains in the country, but before the war there was a considerable though diminishing export to Germany. Before the war, the value of cocoanut cake as a foodstuff for cattle was hardly known in England, but the war has made a great change in this respect.

The course of the cocoanut oil trade is exhibited in the following statistics :—

TABLE 5.—*Exports of cocoanut oil from the Madras Presidency.*

Year.	Foreign.		To Indian Ports.		Total.	
	Quantity [thousands of gallons.]	Value [thousands of rupees.]	Quantity [thousands of gallons.]	Value [thousands of rupees.]	Quantity [thousands of gallons.]	Value [thousands of rupees.]
		Rs.		Rs.		R.
1909-10 .	2,498	*37,09*	4,922	*73,63*	7,420	*110,71*
1910-11 .	1,890	*33,96*	4,284	*78,25*	6,174	*112,21*
1911-12 .	2,121	*39,66*	4,131	*70,58*	6,252	*110,24*
1912-13 .	930	*18.13*	3,921	*71,70*	4,851	*90,13*
1913-14 .	1,060	*22,48*	3,386	*71,24*	4,446	*93,72*
1914-15 .	1,784	*35,96*	3,368	*57,12*	5,152	*93,08*
1915-16 .	2,016	*38,57*	2,729	*42,81*	4,745	*81,38*
1916-17 .	2,019	*42,53*	2,398	*44,40*	4,417	*86,93*
1917-18 .	2,490	*46,40*	2,790	*40,92*	4,280	*87,32*

Calcutta, Bombay, Rangoon and Karachi all import large quantities of cocoanut oil from the west coast but, before the war, the foreign export trade was on the downward grade. The reason

probably is to be found in the fact that copra is less bulky than cocoanut oil, and while it does not need to be packed in expensive casks or barrels, there is less risk of loss or wastage on the voyage. Germany, moreover, as has already been noted, deliberately encouraged the import of copra for her crushing mills, by admitting copra free of duty while imposing a duty on cocoanut oil. The oil is usually shipped in casks made at Cochin of white cedar (*Dysoxylon Malabaricum*), an exceptionally clean hard grained wood, free from resin or other deleterious matter, which might discolour the oil or otherwise injure its quality. Even before the war the cost of barrels amounted to an extra charge of Rs. 30 per ton, but owing to the scarcity, not only of hoop iron, but also of white cedar, the cost of packing has gone up to many times that figure. The extra cost of packing in expensive casks or barrels might be saved by the use of tank steamers, but the fact that the oil solidifies at a temperature of 68° Far. has hitherto prevented the adoption of this expedient. It is believed, however, that tank steamers have already been used to convey cocoanut oil from the Phillipines to the United States, and no doubt they will make their appearance sooner or later on the west coast, especially as a large copra crushing mill is about to be established at Ernakulam near British Cochin by the Tata Oils Company, Ltd.

Other uses: cocoanut shell charcoal.

Little progress has hitherto been made in the Madras Presidency in the industries based on the use of cocoanut oil. Messrs. Best & Co., however, refine cocoanut oil at Pondicherry, and the product, under the name of cocoatine, has practically displaced the use of *ghi* in European households in the Madras Presidency. Moreover, the Government Soap Factory at Calicut, which uses large quantities of cocoanut oil for the manufacture of soaps by the cold process, has been remarkably successful, and it is probable that after the war there will be a large development of soap making on the west coast. In Ceylon, the dessicated cocoanut industry has attained large dimensions, about 30 millions lbs. being exported every year, but an attempt made some years ago by Messrs. Andrew & Co. of Calicut to introduce the industry into Malabar ended in loss and was abandoned. A new use for charcoal made from cocoanut shells has been found since the war began. The charcoal absorbs gases to an extraordinary degree, and was being made on a large scale near Cochin for use in anti-gas respirators. The shells

were carbonised in pits, but if, as is probable, the demand for cocoanut shell charcoal continues after the war, it would probab'y pay to carbonise the shells in closed retorts and to recover the by-products. Cocoanut shells if carbonised slowly at low temperatures are exceptionally rich in acetic acid, as the following analysis recently made at the Indian Institute of Science shows :—

	Per cent.
Charcoal . .	37·4
Acetic acid .	6·0
Methyl alcohol .	1·54
Tar . .	8·5

The ash both from shells and the husks is extraordinarily rich in potash, and makes a valuable manure.

Coir is the third great branch of the cocoanut industry, exports of manufactured coir (excluding rope) having touched nearly 50,000 tons valued at more than a crore of rupees in 1913-14. The figures are given below :—

TABLE 6.—*Exports of manufactured coir (excluding rope) from the Madras Presidency.*

Year.	Foreign.		To Indian Ports.		Total.	
	Quantity [thousands of cwts.]	Value [thousands of rupees.]	Quantity [thousands of cwts.]	Value [thousands of rupees.]	Quantity [thousands of cwts.]	Value [thousands of rupees.]
		Rs.		Rs.		Rs.
1909-10 .	672	*72,28*	193	*15,05*	865	*87,33*
1910-11 .	635	*68,70*	177	*13,54*	812	*82,24*
1911-12 .	739	*79,76*	215	*16,87*	954	*96,63*
1912-13 .	710	*81,49*	202	*15,79*	918	*97,28*
1913-14 .	766	*88,07*	189	*15,49*	955	*103,56*
1914-15 .	471	*56,27*	213	*16,88*	684	*73,15*
1915-16 .	536	*63,19*	193	*13,85*	729	*77,04*
1916-17 .	558	*63,54*	190	*13,51*	748	*77,05*
1917-18 .	380	*43,50*	253	*18,28*	633	*61,78*

The coir industry: yarn.

The industry is entirely a cottage one. As soon as the nuts are husked, the husks are carried off and buried in pits on the banks of rivers and backwaters. The husks remain buried for at least 8 or 9 months and sometimes are left in the pits for as long as 18 months. When they are taken out of the pits, women beat them with wooden mallets on a stone or block of wood, until the fibres are thoroughly separated from the pith or outer skin. The pith is then shaken out and the fibre thoroughly washed. It is then teazled by being thrown up and down between two sticks, an operation which not only removes any small particles of pith which may still be adhering but also has the effect of mixing thoroughly the long and short fibres. The fibre is then ready for spinning either by hand or by the spinning wheel according to the custom of the locality. This operation is entirely performed by women. Some of the hand spinners are exceedingly expert, and are able to spin with both hands simultaneously. The usual method is to roll out the fibre in lengths of one foot slivers. These slivers are twisted together, other slivers being added as required and the spun yarn being held in position by the toes. The spinning wheel is in use in Travancore near Anjengo and Quilon, but further north spinning is done almost entirely by hand.

The process described above is that followed in the districts such as Anjengo and Alapat, where the best yarn is produced. In some districts, however, the soaking of the husks is dispensed with or is impossible owing to the lack of suitable creeks or backwaters. The resulting yarns are usually coarse in texture and reddish in colour and are weakened by adhering particles of pith. The best yarns are absolutely free from pith and are a bright, many of them almost a golden, colour. All the best coloured yarns are produced in neighbourhoods where the rise and fall of the tide are most marked. The reason is said to be that large quantities of gases are generated by the soaking husks which discolour and render brackish the surrounding waters. The tides wash away these accumulations of gases, and it is in this constant scouring that the value of the tidal creeks and backwaters to the coir industry lies. Husks are frequently soaked in tanks and ponds which are not tidal, but the fibre is never of the same bright colours or of the same durable nature as that obtained from husks soaked in tidal backwaters. All the most famous yarns, Anjengo, Alapat, Ashtamudi,

Parur and Vycombe come from localities which are favourably situated in respect of tidal action, and large quantities of husks from northern districts where conditions are less favourable are sent to Anjengo and other southern places to be soaked. Yarns are named after the district or village in which they were made and are distinguished not only by colour but also by their twist. Alapat and Anjengo are the most high priced yarns, but Ashtamudi, Vycombe, Parur and Karua are also well known. All these yarns come from the neighbourhood of Alleppey or the districts further south. The speciality of Cochin is a thick roping yarn. Calicut yarns (Beypores, K. Ps, Parappanagadis, etc.) are generally speaking of inferior quality.

Yarn passes through many hands before it reaches the shipper or manufacturer. The spinner frequently sells or barters it to the petty shop-keeper, who in turn sells it to the dealer or middleman. The dealer roughly sorts the yarn according to colour and thickness and makes it up into neat round bundles each containing one maund or multiples thereof. In this form it is sold to the dealers at the coast ports, who again sell to the shipping firms or manufacturers. Before export, however, the yarns are carefully re-sorted and are re-wound on wheels into long hanks each about 450 yards long and 2½ lbs. in weight, the object being to ensure that each hank should consist of one continuous length. This re-winding is done by boys who are exceedingly expert in splicing the several ends of yarn together, so that it is often quite impossible to find where the join has been made. Each hank is tied across carefully, so that it is easily separated on reaching its destination. These hanks are then taken to a sorting room and are carefully graded by women according to size and colour. They are then made up into bundles each containing 1 cwt. and are usually shipped in hydraulically pressed bales of 3 cwts. each. Inferior yarns, however, are usually done up in *dholls* (small bundles of 5 to 7 lbs. each) and shipped as broken stowage. The re-winding into long hanks costs the coast firms about Rs. 10 per ton. This extra expense would be saved if the cottagers would agree to splice up the lengths before hanking. But it is not the custom, and all attempts to induce them to supply long hanks have failed.

Matting and rope-making.

The bulk of the manufactured coir exported from the west coast is coir yarn, but the manufacture of coir mats and matting is now an important industry at Alleppey and at Cochin. The looms are

almost all hand looms, and the processes of weaving do not require any special description. Every variety of coir mat and matting is woven, while coir mesh bags are made for carrying apples, tea leaf, onions and other produce. Coir ropes and cordage are another important branch of manufacture. There are no rope machines and the ropes are all made by hand. The foreign export trade in cordage and rope is small, but exports to Indian ports, particularly to Bombay, are considerable. They amounted in 1913-14 to nearly 5,000 tons valued at more than Rs. 7 lakhs.

As the exports statistics given above show, the coir industry has been greatly hampered by the war, and the population of the west coast littoral has suffered severely. The export firms, on the west coast, however, have done their best to keep the industry alive by buying yarn for stock, and the Indian Munitions Board has been able to assist by placing large orders for yarn and matting. Hundreds of tons of yarn and thousands of yards of matting have been supplied by the Board to the army in Mesopotamia and India, while 150,000 square yards of coir screening (similar to the hop screening used at Home) have been supplied every month to Army Head-quarters in France for camouflage purposes, and large orders have been placed for coir mesh bags, which have been found very useful by the Controller of Tanstuffs for carrying tanning bark.

Soap in India.

By Sir F. A. Nicholson, K.C.I.E. and Mr. A. K. Menon,
of the Madras Government Soap Works, Calicut.

The soap used in India is partly imported (about 18,500 tons on recent averages) and partly manufactured (possibly 21,000 tons) in the country. These figures and the statements below exclude a variety of locally made "dhobies' soaps" of unknown quantity and composition.

Introductory.

The main question considered in this article is whether Indian manufacture can, by improvements, not only hold its own against post-war competition but develop so as to supply a growing demand and to permit of exports. Ultimately the answer depends largely on the solution of the major problems presented by the several oils and fats industries, *viz.*, oil pressing whether in factories or village presses; the edible oils and fats industry; the manufacture of glycerine, whether as a by-product in soap making or as a direct product in fat splitting; the manufacture of candles, paint and varnishes; the hardening of fats as edible or technical material. The assistance of agriculture is also an essential factor both in providing a constant supply of cheap vegetable oils and in absorbing the oil cake from the presses. The present article, however, deals with soap merely as an individual industry, and with one ingredient, *viz.*, tallow. Facts and conditions are as shown on the following page :

Imports.

Quantities and aggregate values are rounded to the nearest thousand, but the rates per cwt. are accurate. The average import of soaps in the 6 years, including the war period, was 18,536 tons, or 997 tons in excess of 1912-13, and 393 in excess of 1913-14, this sustained import being due only to a moderate extent to military demands, which did not aggregate above 3,000 tons per annum. Briefly, for some years before the war imports were steadily growing, and the present

TABLE 1.—*Imports of soap into India—Quantities and values of imports.*

(Thousands omitted.)

YEAR.	ALL SOAPS TOGETHER.			HOUSEHOLD AND LAUNDRY SOAPS.			TOILET SOAP.			OTHER SOAPS.		
	Quantity.	Value.	Rate per cwt.	Quantity.	Value.	Rate per cwt.	Quantity.	Value.	Rate per cwt.	Quantity.	Value.	Rate per cwt.
	cwt.	£	£ s. d.	cwt.	£	£ s. d.	cwt.	£	£ s. d.	cwt.	£	£ s. d.
1912-13 . .	351	*476*	1 7 2	298	*309*	1 0 9	37	*146*	3 19 0	15	*21*	1 8 0
1913-14 . .	363	*500*	1 7 6	301	*314*	1 0 10	45	*160*	3 13 9	16	*20*	1 5 0
1914-15 . .	404	*555*	1 7 5	353	*391*	1 2 2	39	*148*	3 15 10	12	*16*	1 6 8
1915-16 . .	374	*564*	1 10 1	315	*354*	1 2 6	46	*188*	4 1 9	13	*21*	1 12 3
1916-17 . .	380	*673*	1 15 5	326	*443*	1 2	47	*213*	4 10 8	6	*16*	2 13 4
1917-18 . .	352	*756*	2 2 11	311	*534*	1 14 6	31	*189*	6 5 6	8	*21*	2 10 3
Average 1912-15 (3 years).	373	*510*	1 7 4	317	*338*	1 1 3	40	*177*	3 16 6	14	*19*	1 7 2

normal supply may be taken as 18,500 tons. The values are invoice values c.i.f. India, but exclusive of duty. War values may be placed out of consideration. The high value of toilet soaps, *viz.*, about Rs. 57 per cwt. in 1912-15, and the low value of household soaps are very suggestive for Indian developments. "Other soaps" include textile, harness, soft soap, etc.

The imports, whether before or during the war, from countries other than the United Kingdom are almost negligible. The following table gives statistics :—

TABLE 2.—*Imports of soap showing countries of origin.*

Country.	Year.				
	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	cwt.	cwt.	cwt.	cwt.	cwt.
United Kingdom	350,703	396,720	360,663	364,085	335,068
Rest of Empire	502	1,049	2,133	(*a*) 10,172	(*b*) 7,396
TOTAL BRITISH EMPIRE	351,205	397,769	362,796	374,257	342,464
Germany	1,041	304	7	..	..
Italy	2,202	1,201	788	67	5
Austria-Hungary	3,875	1,842	..	55	4
Japan	907	1,101	7,189	3,727	7,190
United States of America	1,801	701	2,710	1,021	2,271
TOTAL FOREIGN COUNTRIES INCLUDING OTHERS.	11,563	6,726	11,455	5,904	9,486
GRAND TOTAL	362,860	404,495	374,251	380,161	351,950

(*a*) 8,325 from Straits Settlements.
(*b*) 5,776 " " "

It will be noticed that, even before the war, little over 3 per cent. of the imported soap came from foreign countries. Also that Japan came to the front as soon as war had fairly begun.

The following table gives the classes of soap imported :

TABLE 3.—*Classes of soap imported from different countries.*

Class of soap.	Country.	Year. 1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
		cwt.	cwt.	cwt.	cwt.	cwt.
Household and laundry (bars and tablets).	United Kingdom .	300,215	351,456	311,459	310,593	300,272
	Rest of Empire .	341	713	1,844	9,693	7,021
	Foreign Countries .	813	805	1,984	232	(a) 4,225
	TOTAL .	301,369	352,074	315,287	320,518	311,518
Toilet soap . .	United Kingdom .	36,326	34,402	37,280	41,182	26,858
	Rest of Empire .	220	281	303	484	176
	Foreign Countries .	8,703	4,624	(b) 8,700	(c) 5,601	(d) 4,710
	TOTAL .	45,330	39,307	46,283	47,267	31,744
Other soaps . .	United Kingdom .	14,102	10,862	11,924	6,310	7,938
	Rest of Empire .	31	33	8	16	183
	Foreign Countries .	1,059	1,297	771	71	551
	TOTAL .	15,152	12,192	12,703	6,397	8,672
	GRAND TOTAL .	362,860	404,478	374,273	380,182	[illegible]

(a) 4,181
(b) 5,355
(c) 3,502
(d) 2,540
from Japan.

Of soaps from foreign countries, the bulk (76 per cent.) in 1913-14, is toilet soap, of which, in that year, Austria-Hungary sent 48 per cent. ; Japan now takes the lead.

The subjoined table gives some information as to amount of soap produced in various parts of British India, but must be read subject to the explanations which follow.

TABLE 4.—*Production of soap in British India by provinces.*

Province.	Factories producing.		Production in tons per annum.		
	Above 600 tons per annum	Below 600 tons per annum.	Bar soap including twin tablets.	Toilet soap.	Other soaps.
			Tons.		
Bengal . . .	2	1	4,800	Not stated	Trifling except 1,800 tons "dhobi soaps" in Burma, which however are priced at bar soap rates and are probably similar.
Madras . . .	..	1	240	350 tons.	
Bombay . . .	2	10	3,660	Not stated.	
Sind . . .	2	4	2,320	"	
Punjab . . .	..	1	64	"	
Delhi . . .	..	10	152	350 tons	
United Provinces .	..	5	520	6 tons.	
Central Provinces .	..	4	264	Trifling.	
Burma . . .	5	1	8,700	Not stated.	
TOTAL .	11	46	20.720	706	

These figures, which take no account of factories in the Indian States, are taken from statistics collected by the Indian Munitions Board, but they must be regarded as potential rather than actual, being the aggregate of statements made by factories, including cottage factories, as to their ability to supply soap. The quantity is rather what could be made at once if orders were given and time allowed, rather than regular output. On the other hand a considerable factory was under construction in the Bombay Presidency, and many petty ones, as in Madras, have been omitted because of the small quantity produced. Some factories also allege that on demand their output could be increased by an aggregate addition of 7,000 tons annually. Further, a firm in Allahabad had works under erection and promised 400 tons per month of bar soap alone, while another in Bombay, also in

Quantities and values of Indian soap produced.

building, promised 150 tons per month. If these statements are correct, the present output of all soaps may be put at about 21,500 to 22,000 tons, with works under erection which will add 6,500 tons of good class soap, besides a possible increase on demand by existing factories of about 7,000 tons. Hence, there is a possible output at present of 28,000 tons and a potential output of 35,000 tons. Soaps declared as "dhobies soaps" are excluded from these figures, but the output of Burma, and to a less degree, of the other provinces includes soaps which obviously come under that category, whether so named or not. But since the phrase "dhobies soaps" is used somewhat colloquially as the equivalent of "laundry soaps" it seems that, especially in Burma, where some "dhobies soaps" are priced at Rs. 28 to Rs. 16 per cwt., these should have been added, in which case the output of laundry bar soap should be increased by about 1,500 tons annually.

Out of the 48 bar soap factories many are very petty, offering to supply only 8, 9, 20, 50, etc., cwt. per month. Thirteen working factories actually profess ability each to supply 50 tons and upwards of bar soap per month, their aggregate being about 17,000 tons annually: nine offered 10 tons and upwards per month aggregating 2,400 tons per annum; and 26 offered less than 1,000 tons annually between them. Toilet soaps are known to be made in considerable quantities, but only 19 factories have reported, their output being trifling except in Delhi and Calicut. The total promises of toilet soap aggregate about 710 tons or about 9,500,000 cakes at six cakes per pound. But a large addition should be made for good class factories which have not stated their toilet soap output. In all 56 factories are entered as going concerns.

Prices.

Prices are largely a gauge of quality, especially in bar soaps, which form the great bulk of Indian-made soaps. Figures are not available before 1918, in which year they were inflated by the large demands for the army and by the high prices of caustic and other material. The prices at which factories made provisional offers of soap varied from Rs. 35 to Rs. 8 per cwt., the former being or professing to be first-class soaps equal to high class English bar soap, the latter being, in their lowest grades, soap more by name than quality. The following table shows approximate figures for bar soaps (excluding "dhobies soaps") but the manufacturers' statements are often obscure and doubtful.

TABLE 5.—*Quantities of soap produced, graded according to price.*

Price per cwt.	Province.	No. of factories offering.	Quantity offered per annum.	Totals of grades.	Percentage of grades.	REMARKS.
Rs.			tons.			
35	Punjab . . .	1	32			Bar soap and twin tablets only. Dhobies soap, a small quantity of saddle soap and about 730 tons toilet soap are omitted. The tendency in each grade is towards the lower price in each grade. Where a factory produces two or more grades, the total production has been divided up among such grades. Prices are for 1918 only, and are therefore above normal. The word "grade" as here used, has reference to prices and not to qualities.
	Delhi . . .	2	63			
	Central Provinces .	1	4			
30	United Provinces .	1	5			
	Madras . . .	1	219	First grade 1,321	*6·6*	
	Karachi. . .	1	600			
28-25	Punjab . . .	1	32			
	Delhi . . .	2	70			
	United Provinces .	1	278			
25-20	Karachi. . .	8	1,600			
	Bombay . .	8	1,333	Medium 3,191	*15·8*	
	United Provinces .	1	258			
20-16	Karachi. . .	1	23			
	Bombay . .	8	1,574			
	Bengal . . .	1	3,360	Second grade 7,750	*38·5*	
	Central Provinces .	2	93			
	Burma . . .	5	2,700			
16-12	Karachi. . .	2	45			
	Bombay . .	5	716	Third grade 3,440	*17·1*	
	Burma . . .	3	2,688			
Under 12	Bombay . .	2	68			
	Bengal . . .	2	1,440	Lowest grade. 4,430	*22·0*	
	Central Provinces .	1	225			
	Burma . . .	4	2,700			
	TOTAL .	..	20,159	20,159	100·0	

The prices of toilet soap are not entered since they are mostly quoted by cakes of unstated and varying weight; they run from $4\frac{1}{2}$ to 10, 12 and even 14 annas per 3 cakes, boxed or loose.

The table of prices indicates roughly the general run of prices. High-priced soaps only form one-sixteenth of the output, while soaps from Rs. 10 (in one case Rs. 8) to Rs. 20 per cwt., averaging about Rs. 14, are above three-fourths (77·6 per cent) of the whole.

Hence 2 annas per pound, at which price, even in 1918, one of the largest firms offered 200 tons or more per month, may be taken as the ruling price, with possibly a slight reduction in normal years. It will be noticed that Bengal does not appear until the grade of Rs. 20 and under; while Burma is still more noticeable in the three lowest grades.

The prices of imported soaps averaged £1-1-0 per cwt. for laundry and household soaps until recently, or, at the then exchange, Rs. 15-12-0. Adding duty, etc., the wholesale average price in India would have been about Rs. 17 or 18 per cwt. Since a large proportion was admittedly of well known high-grade soaps priced at between Rs. 20 and 28, much of it was of inferior grades saleable wholesale, as is known, at or even below Rs. 14 per cwt. or per case of 108 lbs. We have here a measure of the competition to be met. Similarly, imported toilet soaps averaged till 1915 to 1916 inclusive, £3-17-6 per cwt. or, at the then exchange, 8½ annas per lb.

Quality.

"Soap" is a very indefinite term and covers immense quantities of material which is merely a mixture so faked as to seem like true soap. Taking "genuine settled" soap as the standard of bar soap with, say, 62 per cent fatty acids (the important factor in soap values) 7 per cent alkali, and 31 per cent moisture, saleable at present at Rs. 28 to Rs. 30 per cwt., it is obvious that many soaps both imported and indigenous fall far below such standard, and while much is sufficiently good to act as a useful detergent, much is mere water and fillings of no value except to produce weight and to retain water.

The table of prices shows Indian-made bar soaps at from Rs. 8 and Rs. 10 to Rs. 35 per cwt., and since raw material—except rosin—is fairly even in price throughout the country, it follows that the manufactured article is of the most diverse composition. For if oils and fats be taken at the low average price of Rs. 16 per cwt.—a price much below present rates—and form settled soap at the accepted rate for genuine soap, at three cwt. soap to two cwt. of oils, it is obvious that when caustic, fuel, labour, supervision, depreciation and interest, packing and office charges, profit, etc., are added, it is impossible to sell genuine soap at many of the low rates offered. Many indeed of the soaps offered by large and high class firms are of good material and make, and the *present* hope for the Indian industry is with these firms until the smaller manufacturers can be instructed. But as regards many other soaps,

they cannot, owing to crudeness of manufacture, bad composition, bad appearance, insufficiency of fatty acids and superabundance of water and alkaline material, compete with imported soaps of similar price but better make.

Analyses of a few soaps, of which the prices are not stated, from one province show fatty acids ranging between 15 and 20 per cent., water from 53 to 66·4 per cent., and sodium chloride from 8·4 to 18·2. These analyses and the general prices quoted from that province show that they are merely hydrated alkaline soaps, in which advantage is taken of the ability of saponified cocoanut oil to retain large quantities of water, especially when aided by salt and other alkalis. Examination at Calicut of many such soaps, mainly from the Madras Presidency, show similar characteristics; soaps shrunk to half their weight and size, distorted, and discoloured; soaps covered with snow-like crystals of alkali, mainly carbonate; soaps so imperfectly made as to be acutely caustic in parts, while other parts are unsaponified. Some soaps are made with empirical or, rather, mere guess work quantities of oils, sodium carbonate, and caustic lime boiled up together so that the resulting "soap" is an indefinite mass of soap, unsaponified oils, sodium carbonate, calcium carbonate, and insoluble lime soap. Visits to factories in another province showed that the soaps were made, as is common in India, by the "semi-boiled" process, a speedy and easy but very crude method, by which imperfect soaps are formed containing large quantities of alkaline liquor and the whole of the more valuable glycerine. So far as the Madras Presidency is concerned, many locally made soaps are so badly made that they cannot even deceive.

Liquored and filled soaps are also to be found among imported soaps, and partly account for the low average price of imported bar soaps, but, in general, imported cheap bar soaps are so skilfully made that they do not so readily betray low quality, being largely able to retain form, colour and general appearance. But soaps have been imported (1914) which were unsaleable in Madras from loss of weight (50 per cent.) and consequent distortion. In a case just reported in England a huge parcel of bar soap made "*specially for export*" was the subject of a suit, and was said to contain only 11 per cent. fatty acids and above 80 per cent. of water. The Judge characterized it as "soap and water." Other imported soaps examined at Calicut showed gross quantities of useless mineral fillings, solely intended to increase the weight.

It appears, then, that in order to meet the demand for cheapness and, of late, to obtain rapid and maximum profits from temporary high prices, Indian bar and tablet soaps of most miserable qualities have been flung on the market. These can be but ephemeral and will disappear with the competition of imported soaps and of soaps locally made by instructed persons. The question then arises whether Indian-made soap can, in normal times, compete with imported soap of the several classes which figure as bar and tablet (laundry and household), toilet, and "others", which include textile, harness and saddle soap, soft soap, etc.

As shown above, the average prices of imported and indigenous bar soaps, say Rs. 16 per cwt., are not dissimilar, and if the local quality can be improved, India should more than hold its own. The points normally for and against the Indian industry at present may be summed up as follows :—

For—

The manufacture of soap in India: advantages.

(1) There is an abundant and increasing supply of all oils and fats, except the palm oils and tallow, grown alongside of factories, suitable for hard or soft soaps, and in the freshest condition (see Appendices).

(2) Certain of these oils, notably cocoanut, lend themselves to simple and rapid methods of manufacture and to the cheaper grades of soap, which, notwithstanding the claims of high standard soap, will always be in demand.

(3) Labour, land and consequently single-storey buildings, are all cheap.

(4) Taxation is, in comparison with other countries, low or nominal, especially for small factories and outside municipal areas.

(5) The markets are at the doors of the factories and consequently the expenses attending imported soaps in the way of freight, packing, and export charges are absent.

(6) There is an import duty of 7½ per cent. *ad valorem.*

(7) All factories can suit their goods to local prejudices or wishes in the composition of soaps, their solubility in hard and brackish waters, appearance, perfumes, etc. : and can produce soaps without the animal fats (beef and mutton tallows and pig fat or lard) so largely used in imported soaps.

(8) Petty factories run by men instructed in Government institutions can be established in hundreds of centres, buying and

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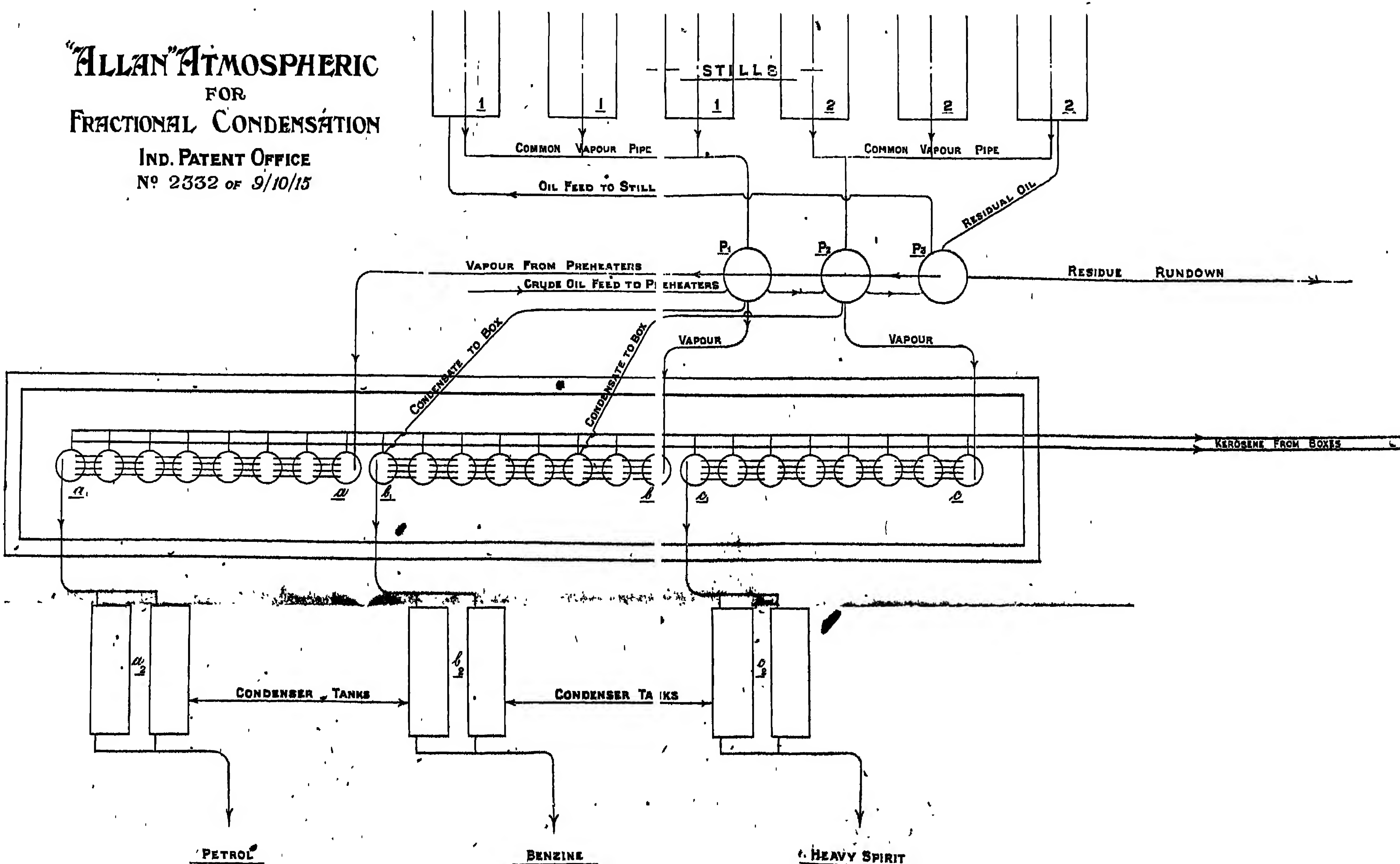

selling in purely local markets, and content with minimum profits on a minute fixed and current capital.

(9) Fish oils, available either crude or hardened for certain uses, are cheap.

Against—

Disadvantages.

(1) There is an absence, complete or comparative, of the masses of cheap materials which partly take the place of tallow, such as kitchen stuff, melted fats, bone fat and bone grease, waste greases from ships, numerous factories, railways, etc.; as well as cotton-seed soap-stock (mucilage) and the low-grade oils and foots from the great oil presses, hardened fish oils, etc., available to the Western soap maker.

(2) Caustic alkalis are not made in India on any scale and must be imported.

(3) Individual factories are small as compared with the immense and carefully organised soaperies of the West, where the manufacturers even own plantations and lines of steamers to cheapen their raw material.

(4) There are no great markets for raw materials such as are at the doors of Western manufacturers, where by trade organization the best goods at competition prices can be obtained in any quantity and on big forward contracts.

(5) There is a comparative absence of instructed soap makers and chemists and of experienced and competent foremen and soap artisans, such as are universal in the West.

(6) Capital is often wanting, with the result, *inter alia*, that goods are put on the market poor in composition and appearance, and makers are unable to survive determined competition and the dumping of goods at low or cost prices.

(7) There is insufficient initiative and push, partly due to want of capital and knowledge, partly to discouragement in the face of organized competition, partly to tropical conditions of life.

(8) The connected industries, not merely those of the oils and fats group, but of necessary side lines such as box and barrel makers, carton and cardboard box makers, lithographic and colour designers and printers on the large and expert scale, etc., are either wanting or, where they exist, weak.

(9) The recovery and distilling of glycerine is difficult owing to the smallness of individual output, the expense of plant, and the

length and expense of lead for parcels of crude glycerine to central distilleries.

(10) The recent rise in exchange adds to other difficulties.

Indifferent items: rosin.

Rosin, (see page 376) produced from Bhowali and Jallo, should be, for the north of India, as cheap as elsewhere. Before the war it was quoted at Rs. 8-12-0 to Rs. 9-9-0 f o r. Bhowali, and the present very high prices are probably temporary. These compare fairly well with rosin in England at, say 10 to 11 shillings per cwt. But the rail charge to the south adds 50 per cent. to cost and brings it close to the imported pre-war rate of Rs. 15 per cwt.

Tallow.

The important item of tallow is discussed later.

Plant.

Plant need not be expensive, since for small factories plant such as was used in British factories 50 years ago is perfectly suitable and can be locally manufactured, while labour is so cheap that manual processes can be adopted in place of expensive labour-saving devices. Land being cheap and free ventilation necessary in an Indian climate, single-storey buildings of simple design are alone needed, except for a boiling house in cases where the best modern arrangements are desired. Fuel is fairly cheap in certain centres: in the north of India coal is close at hand and cheap; while wood fuel is cheap on the West coast.

Fuel.

Moreover, there is considerable gain in the natural temperatures of India, both as regards the water used in soap making, drying of soaps, the evaporation of spent lyes for glycerine, and the adoption of the cold process which needs absolutely no fuel.

As regards *disadvantages* (see above).

Discussion of the various disadvantages.

(1) Even the waste greases of Western countries are only cheap as compared with good tallow. Pre-war prices ranged from 20 to 21 shillings for waste and bone greases, and 26 to 32 shillings for bone fat. In India few oils run above Rs. 18 (24 shillings at Rs. 15 per £1) in normal times, and these require no refinement or manipulation. Even in India there are occasional sources of waste fats in large cities and seaports, and these should be organized. There are also many factories where bones are steamed for fertiliser material or where bone char is made. Although Indian bones are deficient in fat, and are usually putrid at the factories, the fat

(and with it some coarse glue fit for size) may be recovered from the waste waters of the digesters. The use of lime or bleaching powder would lessen the local nuisance, and the grease would partly form lime soaps: this matter is under enquiry at Calicut, where there are bone factories. The cotton-seed soap-stock is procurable in small quantities in Bombay oil presses, but this very important cheap soap material, the cheapest available in America, awaits—as do other industries—the development of the pressing and refining of cotton-seed oil.

(2) Absence of caustic is not very material, since in normal times the purest British, 76-77 per cent., caustic is obtainable at £10 or thereabouts per ton in drums f.o.b., and with duty and freight, etc., at about £14 to £15 in Indian ports, possibly these prices may not be again reached for years. Caustic soda is however already made in India and it is possible that there will be further developments in this line of manufacture (see page 68). Since the caustic used may be taken as 10 per cent. of the weight of finished soap, the matter is, however, not of the first pecuniary importance. Caustic potash on the large scale will always be imported, but a sufficiency for local needs is occasionally obtainable, as at factory centres where wood fuel is burnt, by leaching the wood ashes from the furnaces. Attempts have been made and should be successful by organization, at obtaining potash from municipal incinerator ash.

(3) The smallness of factories cuts both ways. Such factories supplying local needs are, or recently were, numerous in Europe. In India where Rs. 100 nett profit per month is a decent income for a small capitalist, a petty manufacturer working at boiled and cold process soap, his own expert, buying and selling locally, without office or advertisement, commission, and other over-head expenses, may entirely distance outside competition, especially in toilet or semi-toilet soaps. But he must be thoroughly instructed at a modern factory.

(4) to (8) These disadvantages are only remediable by time, experience, and the development of the whole oils and fats industries.

(9) As regards glycerine, most of the small factories will probably work on those processes in which the glycerine is not separated but remains in the soap. This is a loss, since even crude glycerine is twice as valuable as soap, but the loss is largely compensated by the ease, rapidity and cheapness of manufacture, by the im-

provement to the soap, and by the weight added to the soap by the unseparated glycerine. Large factories will have their own recovery plant, and experiments tend to show that crude glycerine may be cheaply recovered in this climate without the usual vacuum plant, the crude being then sent to a central distillery. But the difficulty may be turned by the establishment of a central factory for splitting oils and fats, especially by the castor ferment process, in which case the glycerine would be dealt with at the factory and the fatty acids sold to small soaperies for saponification with carbonates.

(10) The rise in exchange favours imported soaps. At an average of £1-1-0 per cwt, soap entered India at Rs. 16, when the pound sterling was worth Rs. 15. The cwt. will certainly continue to fetch Rs. 16, which will be remitted as £1-4-6, when Rs. 13 represent the pound. Or conversely, the exporter can afford to sell his cwt. of soap at Rs. 2 below his former prices, and thus defeat, *pro tanto*, the Indian producer.

Tallow.

Tallow in Western countries is a most important ingredient in hard soaps, and in addition to large local supplies is imported in immense quantities from Australia and from the Argentine, mainly mutton and beef tallows respectively. Indian soaps do not require tallow in anything like the same quantity proportionate to soaps made, since vegetable oils (notably cocoanut), and vegetable fats or semi-fats are abundant and cheap. Moreover, large classes of Indian consumers demand soaps made without animal fat of any sort, and these are being supplied A large firm states that its bar soaps are made solely from vegetable oils and fats, and the cold process and semi-boiled soaps are readily so made. Hence the tallow question is less important in India than elsewhere.

Owing to the leanness of Indian cattle and sheep, to the comparative paucity of animal food as an article of diet, and to the household economy which utilises every particle of fat in the animal food used, tallow is not abundant in India, and is hardly procurable except at large centres of mixed population. Statistics for the country are absolutely unobtainable. Twenty to thirty tons per month are the outside estimate as at present available on the whole Madras West Coast; and as much of this is required for other purposes, such as caulking ships, etc., an almost negligible quantity is available for soap making. But seeing that Australia is much

closer to India than to England, it should be easy to organize a diversion of part of the Australian tallow to India at favourable prices. Australian tallow of good quality was offered during the war at Rs. 35 per cwt. and should shortly be much less.

Local tallow is of fair quality though crudely produced, *viz.*, by boiling the fatty tissues and waste pieces at the various small slaughter houses. The crude and impure stuff is collected by merchants, melted and strained, and sold to consumers. The pre-war price at Calicut was Rs. 25 per cwt., but has advanced to Rs. 35 and Rs. 37. As usual, tallow is not infrequently adulterated, generally with cheap starchy materials. This, of course, is a pure fraud.

Substitutes for tallow and waste greases.

India possesses in abundance oils and fats which can even advantageously take the place of tallow and greases; *e.g.*, those of the *Bassia longifolia*, *Schleichera trijuga*, *Hydnocarpus wightiana*, *Vateria indica*, and others. Cocoanut oil permits of the manufacture of thoroughly firm soaps without tallow, in combination with various other oils and vegetable fats. For soft soaps, fish oil and stearine are abundant on the West Coast.

Hardening of oils.

But it is in the hardening of oils by hydrogenation that a remedy exists for the paucity of tallow. Fish oil from Tanur has been so hardened into a hard, inodorous "stearine" of various titers, perfectly suitable for use in soap making and otherwise, and its faint odour, similar to that of "composite" candles, has not changed in four years. Thousands of tons of oil are made annually on the Madras West Coast, and more will soon be available on the Bombay coast. Fish oil-cum-stearine is priced around Rs. 150 per ton, and if hardened at Rs. 100 per ton (£5 and less in Western countries), the cost of the hardened product would be Rs. 12-8-0 per cwt. or half the pre-war price of tallow. The vegetable oils can similarly be hardened especially those of the lower grades, and have the advantage that they can be hardened while fresh and almost free from acidity. Such hardened vegetable oils can be used in making hard soaps suitable to the markets which demand purely vegetable soaps. It appears, therefore, that the use of hydrogenation, especially where hydrogen can be locally obtained as a by-product in electrolytic industries under contemplation, will entirely compensate for the comparative paucity of tallow.

Toilet soap. The Indian public delights in toilet soaps, free from animal fat and strongly perfumed. High-class imported soaps from various makers, and Indian-made soaps are sold even in fishing villages, and the cheaper class by hawkers on railway stations, etc. As shown above, the possible output from a few factories which reported was nearly 10 million cakes. The abundance and suitability of high-class materials, the existence of perfumes suited to Indian tastes, the nature of the industry which can be conducted on the small scale, and the *ad valorem* duty which is considerable on soaps worth £3 to £4 per cwt. should give India a preponderance in this class of soaps, both for local use and for export. But "appearance" both in size, shape, perfume, colour, gloss, beauty of design, and attractive packing, must be, and at the Madras Government Factory at Calicut is being, carefully studied. A list of ordinary Indian perfumes is given in an appendix

Other soaps. For textile purposes, and indeed for laundry work, much of the Indian soap is unfitted; but the demand for suitable soaps in the cotton and woollen mills (which require separate classes of soaps) is considerable and should be met by Indian-made soaps. The Calicut factory has supplied cotton mills with such soaps which have been declared satisfactory as to quality and price.

Harness or saddle soap is made by several Indian firms, but the 1918 prices charged are very high, possibly because of the use of potash. Soaps without potash but containing fish oil have been supplied from Calicut and found eminently satisfactory by military units. The demand is considerable and should be met.

Soft soaps proper, made with potash instead of soda, have been almost out of the market owing to the cost of potash. These will now be revived, and fish oil is available for a certain class. Fish oil has been considerably used by the Calicut factory in making a cheap insecticidal soda (and rosin) soap in paste form, of very high value and ease in use as a wash or spray on coffee and other estates, mango trees, etc., against insect pests.

Adulteration. The examination of various soaps coupled with the analyses and quantities mentioned above, shows that the gravest difficulties arise from adulteration. If adulterated, that is liquored, hydrated soaps full of alkaline and

inert material and largely water, are imported, the local manufacturer must follow suit or be knocked out. Or, conversely, if the Indian manufacturer is allowed to make goods which he calls soaps, but are largely water, salt, carbonate, earthy materials, etc., the markets will be filled with rubbish. It is on record that a good deal of the soap supplied to troops during the war gave rise to complaints on account of poor quality. In any ease, the consumer is the loser, while there could be no export trade worth the name for such soaps. Seeing that the term "soap" covers such wide grades, *e.g*, in bar soap from genuine settled soap to merely fakes, priced at from Rs. 30 per cwt. to Rs. 8, while even toilet (imported) soap of excellent outward appearance was found to be a mass of earthy material, it is essential in the interests of the consumer, the industry, and the export trade, that customs and legislative action be taken. This however cannot be discussed here.

The need for technical instruction.

The enquiries made at Calicut even by considerable firms and by various petty manufacturers, actual or proposed, and the impossible soaps, distorted, discoloured, efflorescing, of stony hardness or deliquescent, acutely caustic and saline, semi-saponified, etc., examined there, show that there is immense need of free and full instruction in the technology and economy of the art

This duty is one of the immediate future, and it is obvious that such instruction can only be given in working Government factories, since soap making in its various classes, grades, and operations can only be learnt by making soap. The plant can best be copied from running plants which have been expressly worked out to suit small capital, local conditions, specific processes, particular classes of oils, and cheap labour, and the laboratory and class teaching can be suited to the training of the several grades of expert, manager, foreman, artisan. No private or partly private factory can or would give such instruction for the development of rival factories. The giving of this public instruction after full experiment, the collection of sufficient data, and the erection of a properly provided factory, is the *raison d'être* and object of the Madras Government factory at Calicut.

The most useful and common oils and fats suitable for soap making are given below.

APPENDIX A.

For Soda Soap (Hard Soap).

Table 1.—*Oils and fats actually used in Malabar.*

No	English name.	Scientific name.
1	Cocoanut oil (fine and inferior qualities) . .	*Cocos nucifera.*
2	Groundnut oil . . .	*Arachis hypogea*
3	Marotti oil	*Hydnocarpus wightiana.*
4	Punna oil	*Calophyllum inophyllum.*
5	Poovam oil	*Schleichera trijuga*
6	Mohrah oil	*Bassia longifolia*
7	Pongam oil	*Pongamia glabra*
8	Castor oil	*Ricinus communis.*
9	Dupa fat	*Vateria indica.*
10	Tallow (mutton, beef, buffalo) . .	......
11	Rosin or colophony	......
12	Fish oil stearine (sardine oil stearine) for saddle soaps.	*Clupea longiceps*

Table 2.—*Other oils and fats available.*

No.	English name.	Scientific name.
1	Cotton oil	*Gossypium.*
2	Kokum butter (mangosteen oil) . .	*Garcinia indica.*
3	Mowra fat	*Bassia latifolia.*

N.B.—All the oils in Table 1 are abundant. Items 3 to 6 and 7 are abundant in the forests and road sides and could be easily collected in large quantities. The annual output of Dupa fat in Mysore (Shimoga District) and South Canara is estimated to exceed 2,000 tons.

Table 2.—Kokum butter is obtained in large quantities in the Konkan, Ratnagiri and Karwar Districts in the Bombay Presidency. It is also obtained in and around Goa.

APPENDIX B.

For Potash Soap (Soft Soap.)

Table 3.—*Oils and fats actually used in Malabar.*

No.	English name.	Scientific name.
1	Ground nut oil	*Arachis hypogæa.*
2	Sardine oil (from) . . .	*Clupea longiceps.*
3	Shark liver oil	......

Table 4.—*Other oils and fats available.*

No.	English name.	Scientific name.
1	Cotton seed oil	*Gossypium.*
2	Linseed oil	*Linum usitatissimum.*
3	Safflower seed oil	*Carthamus tinctorius.*
4	Poppy seed oil.	*Papaver somniferum.*
5	Niger seed oil	*Guizotia abyssinica.*
6	Rape seed oil	*Brassica campestris.*

APPENDIX C.

Table 5.—*Available indigenous perfumes.*

No.	English name.	Scientific name.
1	Lemongrass oil.	*Cymbopogon citratus.*
2	Citronella oil	*Andropogon nardus.*
3	Sandalwood oil	*Santalum album.*
4	Linaloe oil	*Bursera delpechiana.*
5	Vetivert (khas-khas) . . .	*Vetiveria zizanoides.*
6	Eucalyptus oil	*Eucalyptus globulus.*
7	Eucalyptus citron scented . .	*Eucalyptus citriodora.*
8	Thymol and thymene . . .	*Carum ajowan.*
9	Wintergreen oil	*Gaultheria procumbens.*
10	Ginger grass oil	......
11	Palmarosa	......

The Utilisation of Indian Bitterns.

By Dr. H. E. Watson, *Indian Institute of Science, Bangalore*, and R. L. Mackenzie Wallis, *Industrial Chemist to the Government of Bombay.*

Composition of sea water.

A large proportion of the salt manufactured in India is made by the evaporation of sea water. As is well known, sea water does not consist solely of common salt (sodium chloride), and water, but contains a number of other ingredients, the more important of which are magnesium chloride, magnesium sulphate, magnesium bromide, potassium chloride and calcium sulphate. The following table shows the average composition of sea water in the first column and in the second some figures for a sample taken at Tuticorin, both being parts per 1,000 by weight:

TABLE 1.—*Composition of sea water showing parts per 1000 by weight.*

—	Average.	Tuticorin sample.
Sodium chloride [$NaCl$]	27·25	29·4
Magnesium chloride [$MgCl_2$]	3·29	3·9
Magnesium sulphate [$MgSO_4$]	2·25	2·1
Magnesium bromide [$MgBr_2$]	0·075	..
Potassium chloride [KCl]	0·73	..
Calcium sulphate [$CaSO_4$]	1·26	1·4

There are not many reliable analyses available showing the amounts of potassium chloride and magnesium bromide in sea water collected near the coast of India, but there is little reason to expect that these would differ greatly from values obtained elsewhere.

Composition of bitterns.

In the process of salt manufacture, the salt crystallises out, leaving behind a liquid which is commonly known as bitterns. These bitterns contain all the salts enumerated above except the calcium sulphate, but no attempt is usually made to utilise them. The general practice is to retain them in the salt beds or feeder channels of the salt factory, owing to the mistaken idea that their presence will in some way increase the yield of salt, whereas in reality they merely retard the evaporation of brine. At the end of the season, they are washed away by the rain.

Now as the annual production of common salt in India by the method under discussion is not less than 750,000 tons, it will be seen that the quantity of salts wasted in this way is very considerable. The actual figures are:—

TABLE 2.—*Amount of salt wasted annually in Indian bitterns.*

—	Tons.
Magnesium chloride [$MgCl_2\ 6H_2O$]	103,000
Magnesium sulphate or epsom salts [$MgSO_4\ 7H_2O$] . . .	127,000
Potassium chloride [KCl]	20,000
Bromine [Br.]	1,500

These substances are all of commercial importance. Magnesium chloride is used mainly for dressing cotton thread, and it may also be used for making hydrochloric acid, and metallic magnesium. The requirements for these purposes, however, are comparatively small, and the annual outturn at Stassfurt in Germany, the chief centre of production, is only about 15,000 tons. There seems little prospect at present of increasing the demand, unless the use of magnesia cements can be popularised (see page 379).

Magnesium sulphate is made in rather larger quantities than the chloride, and is chiefly used for finishing textiles. A certain quantity is required for medicinal purposes and some is used for the preparation of sodium sulphate. Several other applications have been suggested but do not appear to be in use. The German production was about 25,000 tons per annum and a considerable quantity is also made in America.

Potassium chloride is a far more important substance than either of the above as it is the starting point for the manufacture of practically all the potassium salts. Until recently, nearly the whole world's supply of these was derived from the Stassfurt deposits, with the result that there is now a very acute shortage of potassium in all forms. Unlike magnesium salts, potassium compounds are required in almost unlimited amounts for the production of fertilisers, and although the quantity given above is not very large in proportion to the total consumption, yet it would form a valuable contribution to the world's supplies. It is in fact nearly equal to the present production of the United States, one of the largest consumers. At the same time it must be noted that this is only one-tenth of the pre-war consumption which reached the enormous figure of 220,000 tons, calculated as KCl, so that it is evident that any potassium compounds made from bitterns would have to be supplemented very largely by those from other sources.

The case of bromine, which is made from the magnesium bromide in the bitterns, is analogous to that of potassium. Except for a certain quantity produced in the United States, the world's supplies of bromine originated in Germany. There is no production of this substance in the British Empire, so that it is of great importance to investigate all possible sources. Although required only in relatively small quantities, bromine in the form of potassium and ammonium bromides is of great importance medicinally. The silver and potassium compounds are indispensable for photographic purposes, while the element itself is in great demand for the manufacture of aniline dyes, and particularly eosine, one of the most important.

Methods of manufacture.

In most salt factories it is usual to run the bitterns out of the salt pans, when the specific gravity of the liquid has reached 30°B. or 1·26. If the liquor is collected in separate pans, and evaporation allowed to continue, a deposit will form consisting of a mixture of epsom salts (magnesium sulphate) and common salt in approximately equal quantities. Owing, however, to the cooling which takes place at night, and the diminished solubility of magnesium sulphate in cold water, most of this substance will crystallise out during the night, while the common salt will deposit during the day when most of the evaporation occurs. Consequently, if the crystals are scraped out of the pans in the morning and evening, the morning

crop will consist of fairly pure magnesium sulphate. These crystals must be purified by dissolving in hot water in lead lined pans, filtering the solution and cooling in wooden vessels The crystals which separate are drained on a centrifuge and are then sufficiently pure for commercial use.

In ordinary circumstances, the liquid, when about half the magnesium sulphate has deposited, will not evaporate further by solar heat, and concentration must be effected by boiling. This can be done in a crude way in an open pan, but it is far better and more economical to use a modern type of vacuum evaporator. When the specific gravity reaches about 1·325, evaporation is stopped and the solution is run out and allowed to cool to about 65°C. During the boiling most of the magnesium sulphate separates out in the form of kieserite, $MgSO_4$, H_2O, together with some sodium chloride, and more of the latter is deposited during the cooling. The liquid is removed from the deposit and allowed to cool still further, when a substance known as carnallite, KCl. $MgCl_2$ $6H_2O$, separates out. This contains practically all the potassium chloride, which can be separated from the magnesium chloride by treatment with water. The liquor from which the carnallite has separated is now concentrated still further until the density reaches 1·40, solids are allowed to settle, and the liquid is run into drums in which it solidifies, forming the magnesium chloride of commerce.

If it is desired to recover the bromine, chlorine must be passed into the last liquor before the final concentration and the bromine boiled off. In certain cases this treatment with chlorine may be found necessary in any case, in order to bleach the liquid, as it sometimes happens that the organic matter present becomes charred at the high temperature of evaporation and produces blackening.

The Kharaghoda salt works.

Attention has recently been drawn to Kharaghoda on the Rann of Kutch, owing to the fact that magnesium chloride is actually being made there with a considerable amount of success. The conditions which prevail in this locality are remarkable, and deserve special attention. Brine similar to sea brine is found in pits many miles from the sea. This liquid is, however, exceedingly concentrated, and frequently saturated with common salt. It also appears to differ from sea brine in that it contains practically no potassium salts. Further analyses will be necessary before this fact can be definitely proved, but there seems little doubt that some of the brines are

remarkably deficient in potassium. The brine is allowed to evaporate, and when the crop of common salt has been collected, the bitterns are run into a second series of pans in which the intense heat and dry atmosphere combine to produce an abnormal degree of evaporation. The liquid in fact becomes very hot on standing, and after a cool night the pans are often full of magnesium chloride crystals. An analysis of these has shown that they may contain 88 per cent. of crystallised magnesium chloride

These conditions are evidently very favourable for the production of magnesium chloride, as much of the evaporation is carried out by means of solar heat, while the absence of potassium salts simplifies the process of purification. It is only necessary to filter the liquid from the pans to remove mud, and boil it down to the necessary density, when the remaining sodium chloride will deposit, and also practically all the magnesium sulphate in the form of kieserite. When these salts are allowed to settle, the clear liquid which will solidify on cooling forms the ordinary magnesium chloride of commerce

Prospects of the bittern industry in India.

At first sight, it would appear that no time should be lost in making use of some of these valuable products which are at present wasted The problem is, however, by no means simple and no pronouncement can be made until a reliable estimate can be formed of the economic conditions which will result after the war. It must be remembered that there is already a great over production of magnesium salts, so that if the foreign article is allowed free access to this country, competition will be of the severest type, and profits a minimum. In any case, there can be no question of export, unless a prohibitive tariff is imposed upon the German products.

The imports of magnesium sulphate and chloride into Bombay in 1914-15 were 1,700 tons and 2,700 tons respectively, while practically none was imported into the rest of India. These quantities are insignificant when compared with the amounts which could potentially be made, but at the same time they seem large enough to warrant the establishment of one or two factories.

A great obstacle to the development of the industry is the scarcity of fuel and often of fresh water in the immediate neighbourhood of the salt factories, while the transportation of the bitterns to a locality any distance away is hardly practicable. Nevertheless, these

considerations do not affect the case of magnesium sulphate, because as already pointed out, this substance can be obtained in a crystalline form in the salt pans It is true that by no means the whole of the magnesium sulphate present in the bitterns can be extracted in this way, but this is of no consequence owing to the immense quantities available. If every salt factory near Bombay were to run off its bitterns into bittern pans and collect the magnesium sulphate, ample supplies for the whole of India could be obtained at a cost hardly exceeding that of common salt, say at Rs. 5 per ton for a product containing at least 60 per cent. of epsom salts. This could be washed in brine and transported in gunnies to a central refinery. As the pre-war price of the article was Rs. 50 per ton (it is now Rs. 200), there should be an ample margin for the costs of transport and refining.

The case of magnesium chloride is not quite so simple. A factory on the site of the salt pans is necessary for its production, and fuel is required. If the evaporation by solar heat is carried as far as is ordinarily possible, it will be necessary to evaporate about 2·40 tons of water per ton of finished product, and the amount of wood consumed should not be more than 2½ tons, and might be reduced to about one-sixth of this quantity.

Two possible centres suggest themselves, *viz.*, Bombay and Kharaghoda. At the former place, removal of potassium salts would be necessary, but this operation is not one of great difficulty, and requires hardly any extra fuel; moreover, if the potassium salts were worked up, an additional source of profit might result. At Kharaghoda, fuel is dearer, but less would be required than in Bombay owing to the abnormal evaporation already mentioned. On the other hand, water is scarce, and there are heavy freight charges to pay both on empty drums for containing the salt, and on the product itself. Before either site was selected, careful estimates of the above quantities would have to be drawn up. Any site on the east coast is almost out of the question owing to the high costs of carriage.

The recovery of the potassium salts is a matter of still greater difficulty. Assuming that the sea water near Bombay has the normal composition, the quantity of potassium chloride which would result as a by-product in the preparation of magnesium chloride would amount only to 200 tons per annum. Now the production of epsom salts and magnesium chloride involves only

very simple operations which can be carried out by practically unskilled labour, but the case of the potassium salts is much more complex than might appear from the very brief description of the process already given. Consequently, the extra supervision charges necessary would probably more than absorb any profits. On the other hand, the production of the potassium salts as a primary product on a large scale might prove a success and the possibilities should be carefully examined.

Finally, there remains the question of bromine. This is a most corrosive and dangerous substance, its preparation requires elaborate apparatus and close supervision, and it is very doubtful if it could be successfully manufactured in this country. Bromine in the form of its salts can of course be recovered and transported as such to a central refinery.

To summarise :—

(1) it should be possible to produce ample supplies of epsom salts for the country's requirements, at a price which would defeat all outside competition;

(2) magnesium chloride is available in quantities far more than sufficient for present needs, and if enough care is paid to the selection of a site for a factory, its manufacture has a good chance of becoming a commercial success;

(3) the question of potassium salts deserves further investigation, and the prospects of this industry cannot be foretold until economic conditions become settled;

(4) it is doubtful if bromine could be successfully manufactured in this country at present.

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The Portland Cement Industry.

By H. A. F. Musgrave, *Superintendent, Government Test House, Alipore*, and H. F. Davy, *Deputy Superintendent.*

Definitions.

The Portland cement industry really forms part of the larger lime and cement industry, which includes lime, both 'fat' and hydraulic, so called 'natural cement' and Portland cement. The present nomenclature of limes and cements is a little vague and there is also a considerable need for having them graded in a more definite way than Vicat's classification affords, so that consumers may have a clearer idea of what they are using. At present, Portland cement is the only material of the class which is governed by a rigid and complete specification. Next to Portland cement rank the natural cements, which may be almost anything from good hydraulic limes to cements but little inferior in strength and hydraulic properties to Portland cement. After this come the hydraulic limes, which contain still less clayey matter in combination with the lime and then the 'fat' limes which are practically pure calcium carbonate. Limes sold as hydraulic are sometimes 'fat' limes, containing a proportion of sand, which are more hydraulic in name than anything else.

Portland cement itself may be "natural" in so far as it is made from limestones containing the requisite proportion of clayey matter without further additions, the great point being that the method employed in the preparation and burning of the raw material and the grinding of the clinker must be such that the finished product complies with the rigid provisions of specifications designed to

secure a cement of the requisite quality. These provisions are such that it is impossible to produce Portland cement on a commercial scale without the use of extensive machinery and without having raw material of fair uniformity. It is true that hydraulic limes may be burnt in country kilns and require no subsequent grinding, while useful natural cements are produced without the aid of very elaborate machinery, but these latter are inferior to Portland cement, and are apt to be variable in quality.

It is necessary to mention these distinctions because inquiries are constantly being received from people who seem to consider that any deposits of ghooting stones, kankar, or lime and clay, in juxta-position in a convenient district, can be transformed into Portland cement with the aid of a plant costing a few thousand rupees and that no special knowledge of the subject is necessary. This is very far from being the case and a warning may not be superfluous. For many classes of work, however, a cementing material of the strength of Portland cement is not necessary and there is plenty of scope for cheaper cements of guaranteed quality. More attention might well be directed to this branch of industrial enterprise

History of cement manufacture in India.

At the time of the outbreak of the present war there were no factories in India producing cement up to the requirements of the British standard specification. The works of the Katni Cement Company and those of the Indian Cement Company at Porbandar were, it is true, under construction and almost ready to commence manufacture for the market, but they did not start fully till 1915, while the Bundi works were making hydraulic lime, the present works not being in full swing till 1916. When it is considered that vertical kiln cement manufacture dates from 1851, that the more modern rotary kiln processes have been in operation in other countries since 1885, that India has been a great and increasing user of cement for many years and that conditions are favourable to manufacture, it is very surprising that up till the outbreak of the war this country had been entirely dependent on foreign countries for its Portland cement But the stimulating influence of the war has been noticeable in this industry; existing firms are anxious to increase their plant, small concerns are being improved and there is more than one project for a new factory under consideration or actually in process of completion

The following table shows the extent to which cement was requred in India even before the war:—

Table showing the imports of cement into India.

Year.	General imports.	Government stores.	Total imports.
	Cwts.	Cwts.	Cwts.
1913-14	2,930,372	570,622	3,500,994
1914-15	2,899,451	415,028	3,314,479
1915-16	2,632,505	216,876	2,849,381
1916-17	1,787,764	163,096	1,950,860
1017-18	1,675,105	36,782	1,711,887

After the war, when work at present in abeyance will be continued, requirements will be greater than ever. The use of ferro-concrete, comparatively new even in the western world, is extending very rapidly, bridges and heavy structural work of all kinds and even ships being made of it. It has even been said that the steel age is now giving place to the cement and steel age, the ferro-concrete age. Comparatively little has been done as yet in India, but little foresight is required to predict a great expansion of this class of work. This in itself will provide a big market for Portland cement. The opening up of Mesopotamia will also afford a large sale for Indian cement, if it be available.

Prospects of manufacture.

Little need be said of the present production of cement because this is fully dealt with in the "Report on Portland cement of Indian manufacture" which was issued recently. The total output of the three chief firms, *viz.*, the Bundi Hydraulic Lime and Cement Company, Lakheri, the Katni Cement and Industrial Company, Katni, and the Indian Cement Company, Porbandar, is now 1,500,000 cwts. per annum, and the whole of this was distributed by the Munitions Board. As the bulk of it was of necessity being taken for war and other Government purposes but little has hitherto been available for the private consumer. The output of these factories being very much short of present demands even, it will obviously not suffice for future requirements, and there is still room for additional works

in other parts of India. The size of the country renders it imperative that works should be distributed in such a way that long rail leads from the factory to constructional sites are avoided A factory more or less on the spot is able to supply at a much lower cost than either the importer of English or foreign cement or the manufacturer situated in another part of the peninsula. At present, there are many important centres which are hundreds of miles from the nearest factory. For example, Calcutta, a port and therefore conveniently situated from the point of view of the importer, is over 650 miles from Katni, the nearest existing works, the Patna district is 300 miles from the sea and almost the same distance from Katni; Lucknow is over 600 miles from Calcutta and about 350 miles from either Bundi or Katni works; while with the possible exception of the Madras works, the output of which is in any case out of all proportion to its needs, the whole of India south of Katni is without a works producing Portland cement to British standard specification

Many other examples could be given but these may serve to emphasize the point sufficiently well. As regards Bengal and Bihar and Orissa, the position is likely to be much improved in the near future. The Orissa Cement Company's works at Garh Madhupur on the Bengal Nagpur Railway, 220 miles from Calcutta, are being re-organised so as to improve the quality of the natural cement made there and with a view to the ultimate production of Portland cement if possible, and it is proposed to erect a Portland cement factory with a capacity of 50,000 tons per annum on the Bengal Nagpur Railway, less than 300 miles from Calcutta. As I have said, the location of sites is not always easy, but necessary materials are available and it should not be an impossible matter to find suitable situations. It is to be hoped that the next few years will see the present state of affairs radically changed so that each important district will be supplied from a factory near at hand.

Fuel and labour.

When suitable deposits have been obtained in a place convenient for distribution, the next important factor is the price at which fuel can be delivered at the works. Each ton of cement requires between eight and ten cwts. of coal for its manufacture, and the price is therefore of first importance. The question of labour presents little difficulty; cooly labour is available almost everywhere and skilled and semi-skilled labour can be attracted.

Effect of climate.

The effect on Portland cement of the higher temperatures and other atmospheric conditions which rule in most parts of India is not very marked, but the low humidity which obtains especially during the hot weather months in most districts sometimes calls for remedial expedients on the part of the manufacturer. The combination of high temperature and high humidity during wet weather also affects the quality of cement, especially if stored carelessly for long periods, but this is common to all cement alike, whether made locally or imported.

In other respects, the climate has little effect The setting of cement is, however, like most chemical actions, accelerated by heat, and the regulation of the setting time, one of the principal difficulties with which manufacturers in all countries have to contend, requires especial care in India. Modern specifications demand low expansion, high strength and extreme fineness, together with slow setting properties and at the same time regulate the amount of gypsum to be used for controlling the setting time. Fineness of grinding tends to lower expansion, hasten setting, and improve strength. The finer a cement is ground the quicker it sets; spreading power and consequent economy are also increased The tendency nowadays is to demand a much more finely ground cement than formerly, and in the British standard specification for 1915 the residue on a 180 mesh was reduced from 18 per cent. permitted by the 1910 issue to 14 per cent. The production of a cement at once slow setting at tropical temperatures and finely ground, conditions mutually antagonistic, is thus rendered more difficult. In spite of this, manufacturers in India have been successful in meeting all conditions. In the interests of manufacturers and users alike, however, the issue of a standard specification for India on the lines of the British standard specification is under consideration, and it is also proposed to grade limes and natural cement.

It does not appear to be generally recognised that the testing of cement cannot be carried out by any but a specialist and that the tensile strength test, however important, is not by itself sufficient to enable a correct opinion to be formed. Tests made by individual engineers under service conditions and with local materials are indeed of the utmost value as indicating what strengths are likely to be obtained on the particular work in hand, but for this purpose crushing tests of 6 inch cubes are of very much greater value than

tensile tests on briquettes. Such tests must, however, be considered as additional and as in no way taking the place of the standard test of quality.

To sum up, the present position of the Portland cement industry is fairly satisfactory. Existing companies have proved that excellent cement can be made in India at a profit and as the prejudice against the Indian product has been overcome, the way is now clear for further development. Both internal and external conditions after the war are likely to be favourable to the industry. The demand will be heavy; owing to the demands for British cement for reconstruction purposes in Europe, the amount available for export to India will probably be small, and conditions in the United Kingdom and high freights are likely to keep the price of imported cement far above the pre-war level. To a lesser extent, the cost of freight will keep up the price of Japanese and Hongkong cement also. These conditions will assist manufacturers in India at a time, when keen competition from abroad might have been very detrimental to the industry.

Lac.

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Lac, the resinous excretion of certain scale insects, has been an article of export for more than three centuries. Although the true lac and other resin secreting insects occur elsewhere, the commercial production of lac in any form is restricted to India (including Burma), Siam and Indo-China. Indo-China and Siam together probably only supply about 2 per cent. to 2½ per cent. of the total production of sticklac, and even of this quantity a considerable proportion is exported to India *viâ* the Straits Settlements for manufacture into shellac. Thus the total export of sticklac from Siam between 1910 and 1915 was as follows:—

Table 1.—*Exports of sticklac from Siam, and French Indo-China.*

Country.	Year.	Cwts.
Siam	1910-11	11,147
	1911-12	6,708
	1912-13	16,272
	1913-14	18,070
	1914-15	6,558
French Indo-China.	1911	4,525
	1912	5,850
	1913	10,318
	1914	4,[illegible]
	1915	1,305

Imports of sticklac from the Straits Settlements into British India in recent years are shown below :—

TABLE 2.—*Imports of sticklac from the Straits Settlements into British India.*

Year	Cwt.
1912-13	8,201
1913-14	13,303
1914-15	977
1915-16	2,110
1916-17	20,274

An average crop of sticklac from all sources is probably well over 725,000 cwt., from which it will appear how considerable a monopoly is held by this country.

Distribution.

There are four main lac-producing areas in India, *viz.* :—(1) the Central India area, including the Chattisgarh, Nagpur and other divisions in the Central Provinces, Chota Nagpur and adjacent districts of Orissa and Bengal and the north-eastern forests of Hyderabad State; (2) Sind; (3) Central Assam and (4) Upper Burma and the Shan States. Lac is grown in other areas, as for example in certain districts of the Punjab, but large quantities are collected only in these four areas. Of these the most important is the large and scattered area in and around the Central Provinces, from which the manufacturers draw the bulk of their supplies. The raw sticklac is manufactured into shellac in a large number of small factories in the United Provinces, Bengal and Bihar, the most important localities being Mirzapur, Balarampur, Imamganj, Pakur and Jhalda. In addition to these, there are two concerns in Bengal where machine-made shellac is manufactured by patent processes.

The insect occurs on a large number of different trees, and the nature of the host is a most important factor in the production of good lac. The best is grown on the *kusumb* (*Schleichera trijuga*), but the *ber* (*Zizyphus jujuba*), *palas* (*Butea frondosa*), *siris* (*Albizzia lebbek*), and *pipul* (*Ficus religiosa*) have all been recommended for the propagating of the insect. In the Central Provinces, lac is largely found on the *kusumb* and *palas* trees, but in Sind it is chiefly grown on the *babul* (*Acacia arabica*).

It has long been recognized that there are several insects of the genus Tachardia which produce lac. The most important is *T. lacca* Kerr, but T. fici, Gr. and T. albizziae, Gr. are also said to yield lac on a commercial scale. It has been found that the Sind *babul* lac has not thrived when transferred to *babul* trees in Bihar, and it is probable that the various grades of lac are not due solely to the trees on which the insects feed, but probably even more to the fact that they are produced by different species of the lac insect. The question is however, one which has not been at all thoroughly investigated, though it is of very considerable practical importance, the various species having not only differing food plants but also differing seasons.

Manufacture.

It is not proposed to discuss here in detail the production and manufacture of shellac, but a short description of the methods employed, and the various stages through which the material passes, will be necessary, as reference will have to be made hereafter to certain points relating to this subject, which are at present disputed or which require fuller investigation. The ordinary process is briefly as follows:—The raw material (*i.e.*, the lac incrusted round the twigs of the tree from which it has been obtained, or sticklac) is first of all removed from the twigs, leaving only a small quantity of wood adhering. The lac is then ground and sifted, the dust being separated, after which it is washed free of dye and the resultant seedlac dried and graded into *granular* and *dust*. The seedlac is then manufactured into shellac by fusing it before a fire. A small quantity of orpiment (trisulphide of arsenic) is frequently added to produce the light yellow colour required in the finer grades of shellac, and a small admixture of rosin is also sometimes made to lower the melting point, and the mixture is fused by twisting it in long narrow bags before an open fire. The molten lac squeezed through the bags is, when sufficiently roasted, placed on a porcelain cylinder containing hot water and spread out uniformly by means of a ribbon of palm leaf into a thin sheet. The lac is now removed from the cylinder, trimmed into a rectangular form, and stretched out into a still thinner sheet. When cold, these sheets are assorted according to colour, and thick pieces, impurities, etc., are broken out, the rejected portions being replaced int he bags for re-melting. In the case of garnet lac, which can only be made from Assam and Rangoon sticklac, if it is to have the required ruby tint, the process used to be

much the same, but the lac was not again stretched after being removed from the cylinder. Garnet lac is, however, no longer made by hand. and its manufacture is now confined to the spirit or "wet" process. In the case of button lac (which is shellac in everything but form) the molten material is dropped on to a smooth surface instead of being stretched.

The principal commercial forms of lac are, (1) *sticklac* (the crude material); (2) *seedlac* or *grainlac* (sticklac crushed, washed and dried, in the process of manufacture into shellac); (3) *shellac* (various grades of the manufactured article in flakes); (4) *button lac* and *tongue lac* (the same, but melted into button or tongue shape). It can be made from any grade of sticklac, but is usually from a medium to good); (5) *garnet lac* (dark red lac melted into thin slab form but not reduced to flakes. It is usually made to contain 10 per cent. rosin, but can be made pure. Lower qualities of this and of button-lac can also be made by an admixture of lac refuse); (6) *kiri* (the residue left in the bags after the melting process, which contains a percentage of lac, sometimes as much as 50 per cent. or even more).

The process above described, as practised in the small up-country factories, demands considerable skill and appears to be on the whole very satisfactory. It is generally admitted that machine-made lac cannot successfully compete, at any rate in certain grades, with the hand-made article. Except for deliberate adulteration (of which there is unfortunately a great deal when the demand is large), hand-made shellac seems to be all that is required for the various purposes to which lac is put, and no complaints are raised by consumers, except as regards adulteration.

Uses.

These purposes are many and various, and have increased surprisingly during the last few years. Besides its use in the manufacture of gramophone records, sealing wax, buttons, lithographic inks, corundum and emery wheels, imitation ivory, oil cloth, etc., and as a constituent of varnishes and polishes and a stiffening for silk and straw hats, shellac is now employed in the making of electric insulators and explosives, and has therefore become an essential military necessity. In India shellac or its residuary by-products (such as *kiri*) are very widely used for the making of bangles, bracelets and toys, as a cement, for the ornamentation of ivory or metalware, for filling ornaments, fastening the hafts to swords, etc., and in the manufacture of innumerable articles of common domestic use in the villages.

The use of shellac in the manufacture of military requisites brought it into great prominence during the war, and arrangements had to be made to secure sufficient supplies for the Ministry of Munitions. The annual requirements were estimated at 50,000 cwt., to be distributed amongst the various allied Governments and by agreement with the shellac shippers in Calcutta a scheme was introduced in January 1917, whereby the shipment of lac was prohibited to all destinations, but licenses were freely given on condition that against every export on private account a consignment of shellac corresponding to 20 per cent. of the quantity exported, and of a certain specified quality, was guaranteed to Government at a fixed f.o.b. price of Rs. 42 per maund of $82\frac{2}{7}$ lbs. Owing to the difficulty of obtaining sufficient quantities of the Government quality, the Ministry of Munitions eventually agreed to take a certain portion of their requirements in Commercial T. N. London standard. The Government percentage is calculated on the amount of shellac in each variety of lac exported, the fixed standard being 90 per cent. in the case of seedlac, 70 per cent. in that of sticklac, and 40 per cent. for refuse lac. Through the co-operation of the shellac shippers, this scheme has worked very successfully and has resulted in the supplying of 80,000 cwt. to the Ministry of Munitions in 22 months since January 1917, a quantity which seems to have been fully sufficient for all purposes.

Trade organization.

The organization of the shellac trade has been criticized on account of the number of middlemen involved. The actual collectors of sticklac sell to *banias* interested in the trade (*arhatias*), who supply the small manufacturers, and between the latter and the actual shippers brokers again intervene. The whole chain is financed by the usual system of advances, even the small manufacturer frequently receiving advances from a Calcutta broker and binding himself to supply that broker only in return. It is obvious, however, that such criticism is ill-founded. Under ordinary conditions, the division of labour and consequent division of risk is essential in a modern industry, and it is clear that the broker plays a necessary part in bringing buyer and seller together and is entitled to a share in the profits of the industry. Were the buyer to take steps to enter into direct relations with the seller or *vice versâ*, he would clearly be entitled to an increased profit on account of increased labour and increased risk. By co-operation among the sellers the mofussil

broker might be eliminated, the whole body of co-operators becoming their own broker, but in that case there would arise the difficulty already experienced in many industries that an increase in profits is merely followed by a reduction of labour, and in consequence the total output would be proportionately reduced. On the whole, there does not seem to be any reason to suppose that the trade could be organized more economically than at present.

In the export trade, the shellac is usually sold on three or four months' sight drafts—*viz.*, 3 months on shipments to Europe and 4 months on shipments to the United States of America,—against letters of credit in London. It is c.i.f. to Europe and c.f. to the United States of America, the importers of that country generally preferring to arrange for insurance themselves. Occasionally small quantities are sold on consignment, but this is not frequent.

Trade statistics.

The importance of the shellac trade is illustrated by the figures given below. It will be noticed that exports have very greatly increased since the period preceding the last ten years, the increase in the value of the trade being accentuated by the rise in prices on account of the war.

TABLE 3.—*Exports of manufactured lac (shellac and button lac) by sea from British India to foreign countries.*

Year.	Shellac		Button lac.		TOTAL	
	Cwts.	Rs	Cwts.	Rs	Cwts.	Rs
1868-69	43,740	*11,66,869*			43,740	*11,66,869*
1878-79	64,498	*22,24,843*	17,114	*5,46,061*	81,612	*27,70,904*
1888-89	81,480	*31,91,125*	21,105	*7,38,702*	102,585	*39,29,827*
1898-99	146,395	*70,97,781*	31,602	*15,62,710*	177,997	*86,60,491*
1908-09	322,953	*246,51,307*	31,415	*23,33,005*	354,368	*2,69,84,312*
1909-10	461,056	*346,48,840*	49,455	*25,40,259*	510,511	*3,71,89,099*
1910-11	357,940	*189,92,267*	31,278	*16,87,206*	389,218	*2,06,79,473*
1911-12	351,175	*178,11,215*	29,684	*16,57,306*	380,859	*1,94,68,521*
1912-13	336,176	*176,81,250*	41,498	*21,86,106*	377,674	*1,98,67,356*
1913-14	275,357	*169,78,228*	21,865	*18,07,059*	297,222	*1,87,85,287*
1914-15	307,845	*141,14,691*	25,526	*12,47,039*	333,371	*1,53,61,730*
1915-16	358,661	*184,73,836*	12,610	*5,72,656*	371,271	*1,90,46,492*
1916-17	324,208	*255,93,984*	3,100	*1,04,875*	327,308	*2,56,98,859*
1917-18	289,726	*339,14,763*	2,759	*4,24,229*	292,485	*3,43,38,992*

of sticklac and other kinds (including seedlac, *kiri* c.), are very small, as shown below :—

Exports of unmanufactured lac (sticklac and other kinds).

Sticklac.		Other kinds		TOTAL.	
Cwts.	Rs.	Cwts	Rs.	Cwts.	Rs
4,136	*66,718*	8,928	*2,43,516*	13,064	*3,10,234*
1,409	*18,604*	141	*2,364*	1,550	*20,968*
193	*2,646*	700	*17,271*	893	*19,917*
730	*23,533*	3,380	*1,29,890*	4,110	*1,53,423*
4,871	*2,45,454*	21,577	*7,17,196*	26,448	*9,62,650*
6,208	*1,73,921*	38,077	*3,59,898*	44,285	*5,33,819*
1,246	*43,390*	31,164	*6,05,714*	32,410	*6,49,104*
1,096	*62,185*	46,051	*7,09,699*	47,147	*7,71,884*
16,628	*3,84,039*	33,861	*8,81,759*	50,489	*12,65,798*
1,196	*51,732*	40,743	*13,21,042*	41,939	*13,72,774*
1,129	*40,699*	32,192	*6,55,005*	33,321	*6,95,704*
3,519	*1,14,190*	42,530	*10,15,130*	46,049	*11,29,320*
7,459	*3,51,845*	46,497	*19,80,995*	53,956	*23,32,840*
1,604	*1,13,260*	28,481	*13,25,782*	30,085	*14,39,042*

seen from the above table that, although prices have rably, there has been no marked increase of exports ufactured article of recent years.

of lac dye have for several years practically ceased. eparate figures are not available for this article, but or preceding years will show that such exports are

TABLE 5.—*Exports of lac-dye.*

Year.	Cwts.	Rs.
. . . . . .	17,748	*7,96,656*
. . . . . .	8,261	*1,06,225*
. . . . . .	334	*8,038*
. . . . . .	6	*200*
. . . . . .	6	*80*
. . . . . .	18	*180*
. . . . . .	..	..

The total value of the export trade now amounts to over 3¾ crores, and even though this figure is partly due to the inflation of prices on account of the war, it will be seen that even ten years ago the value of the trade was 2¾ crores. The following table will make this clear.

TABLE 6.—*Total exports of lac from British India by sea.*

Year.	Cwts.	Rs.
1868-69	74,558	*22,71,758*
1878-79	91,423	*29,87,157*
1888-89	103,811	*40,10,783*
1898-99	182,122	*87,11,144*
1908-09	380,822	*2,79,47,012*
1909-10	554,814	*2,77,10,898*
1910-11	421,628	*2,14,28,576*
1911-12	428,425	*2,01,45,010*
1912-13	428,163	*2,11,33,184*
1913-14	339,101	*1,96,58,001*
1914-15	366,692	*1,00,57,434*
1915-16	417,320	*1,71,76,812*
1916-17	318,349	*2,80,31,690*
1917-18		*3,77,78,034*

Imports are of course very small, and are practically limited to the regular imports of sticklac from Siam and Indo China *via* the Straits Settlements. In 1868-69, the total imports of lac of all kinds amounted only to 1,238 cwts., valued at Rs. 19,814. Ten years later, the imports of sticklac were only 560 cwts. valued at Rs. 13,630. By 1888-89 they had risen to 1,845 cwts valued at Rs. 40,645, and in 1898-99 they stood at 1,552 cwts. valued at Rs. 37,004. The figures for the last ten years are given below, those from 1908-09 to 1911-12 representing imports of sticklac, and thereafter for stick and seedlac combined.

TABLE 7.—*Imports of lac into British India by sea.*

Year.	Cwts	Rs.
1908-09	1,773	87,555
1909-10	865	34,006
1910-11	2,670	83,345
1911-12	1,670	50,145
1912-13	10,903	2,53,334
1913-14	13,318	3,91,082
1914-15	977	33,711
1915-16	2,112	62,784
1916-17	20,804	7,35,107
1917-18	10,349	4,76,329

Estimate of production.

It is difficult to frame any accurate estimate of lac production on account of the difficulty of obtaining reliable information as to the sticklac crop. The whole trade would undoubtedly benefit very greatly if accurate forecasts of the crop were regularly available, but there are very great difficulties in the way of preparing such forecasts. The shellac trade has always been highly speculative, and accurate reports as to the prospects of the crop would minimize the frequent and wide variations in the market value of the article. Unofficial attempts have sometimes been made by persons interested in the trade to forecast the various crops, and recently forecasts by Mr. Lucas have appeared for the "Bysaki", "Katki" and "Kushmi" crops (*vide* "Capital" for April 19th and November 8th 1918). In these, the "Bysaki" crop was estimated at 475,000 maunds,* or (reckoning 18 seers of shellac to every maund of sticklac) 213,750 maunds of shellac or about 107,000 chests. The "Katki" and "Kushmi" crops are estimated at 191,000 maunds and 116,000 maunds respectively, or, taking the former at the rate of 16 seers to a maund of shellac and the latter at 22 seers, 76,400 (38,200 cases) and 63,800 (31,900 cases) respectively. These latter crops are, however, little more

* 1 cwt. = $1\frac{4}{11}$ maunds.

than 8 annas crops, and an average crop may be roughly taken to be as follows:—

TABLE 8—*Estimate of average total sticklac crop*

Place of origin	Mds.
India proper—	
Bysakhi crop	450,000
Jethwa „	25,000
Kushmi „	170,000
Katki „	280,000
TOTAL	925,000
Burma and Assam	75,000
Siam and Indo-China	25,000
TOTAL	1,025,000 maunds or 751,667 cwts.

Practically the whole of this quantity is manufactured in India, only some 10,000 maunds being exported from Siam and French Indo-China direct to Europe. There are thus left 1,015,000 maunds of sticklac, which will give roughly the quantity of shellac shown below:—

TABLE 9.—*Estimate of average production of shellac.*

Crop.	Sticklac in mds.	Percentage of shellac obtained.	Shellac in mds.
Bysakhi	450,000	45%	202,500
Jethwa	25,000	50%	12,500
Kushmi	170,000	55%	93,500
Katki	280,000	40%	112,000
Burma and Assam	75,000	60%	45,000
Siam and Indo-China	15,000		9,000
TOTAL	1,015,000 maunds or 744,333 cwts.		474,500 maunds or 347,966 cwts.

To this figure must be added about 7,000 maunds of *kiri*, which will in turn give about 3,500 maunds of shellac, making a total of 478,000 maunds or 350,733 cwts. of shellac available for export, or 239,000 cases, giving a monthly export of about 20,000 cases. This is rather above the average, but the difference is accounted for by the very considerable internal consumption of the various forms of lac.

Increase of production.

This production might be almost indefinitely increased. Steps are already being taken in Hyderabad State to this end and the increase is practically only limited by the amount of labour available. In the past, the difficulty and expense of obtaining healthy brood-lac has been a serious obstacle to the extending of lac cultivation, and the establishment of nurseries for the supply of such brood-lac in various centres has been frequently recommended. At present, it is not unusual for a lessee who has received a concession for collecting lac in a certain tract to strip the forest of lac in the year in which his lease expires, leaving practically nothing to propagate the insect afresh. Elsewhere the system of royalties exists, the royalty sometimes varying according to the price of shellac in Calcutta. This system, however, appears to have been very unsuccessful in Burma and Assam, and to have led to a very heavy fall in exports. Generally speaking, lac is cultivated and not merely collected wild in the forest, and a fine upon the cultivation of a particular article is bound to influence the cultivator in deciding what crop to cultivate. There is also the great likelihood that, when a royalty is imposed from the top, it will grow greater as it passes through the various channels on account of the exactions practised by subordinates, until it assumes proportions which may weigh very heavily on the cultivator. The solution of the whole difficulty would appear to be the direct leasing of collecting rights to the actual cultivator, so far as possible, and the exclusion of a certain percentage of brood-lac from the concession, this quantity being reserved by the lessor for the propagation of the next crop.

Future problems: adulteration.

In addition to the question of the leasing of concessions, the most important problems connected with the lac trade are, first, adulteration, and, second, the form in which the article may best be exported. Of these, the former is by far the more serious, the latter being now, it may safely be said, practically settled. Complaints on the score of adulteration have been made from the United

Kingdom, from the United States of America, and in Calcutta but not entirely on the same grounds. In the United Kingdom attention has been directed to the large admixture of rosin found in much exported shellac, and it has been suggested that the simplest method of dealing with this would be the standardization of the several forms in which lac is exported. It is generally stated or assumed that an admixture of rosin (up to 3 per cent.) is necessary for the manufacture of shellac, but it is alleged that, when prices are high, shellac may be adulterated with anything up to 50 per cent. of rosin. In the first place, it does not appear to be true that rosin is necessary, and it certainly is not used in all factories. It is perhaps required to soften old sticklac which has been left unmanufactured for 4 or 5 years, when such sticklac is not refined by the spirit process, but there is nothing to show that it is required in any other case. On the other hand there is undoubtedly a certain demand for a mixture of rosin and lac for certain purposes, and in such cases it is a confusion of terms to speak of adulteration, the mixture being simply a blend and not *adulterated* lac at all In any case, the remedy lies not in the defining of standards (as such standards already exist and are well established), but with the importers. These can safeguard themselves by insisting not only that contracts should contain a clause declaring the percentage of rosin allowed (if any) and guaranteeing purity under chemical analysis, but also that a penalty should be exacted on any import of shellac which contains more than a certain fixed percentage This has been done in the United States of America where an admixture of 3 per cent. rosin is allowed in U. S. A. T. N. (corresponding to London T. N.), but in the case of N. Y. T. N. and "superfine" grades the shellac must be pure, and special penalty is inflicted by the Shellac Importers' Association if any shellac is imported containing more than 5 per cent. rosin. In London, on the other hand, although some of the contract forms were modified in 1904 by the insertion of a clause restricting the rosin admixture for shellac to 3 per cent. and for garnet to 10 per cent., no such clause was inserted regarding button lac, and no penalty was insisted on to prevent the import of private standard marks containing a far greater percentage. The result of this omission has naturally been that it is open to an unprincipled importer to buy rosinous shellac and sell it to the small consumer who is unable to afford to buy on chemical analysis, as the pu

article A further difficulty has sometimes arisen through the different results obtained by Calcutta and London analyses, although the Calcutta and American analyses seem to be identical This is a point which could probably be best dealt with by a shellac association, the institution of which is recommended below

With regard to America, the question of adulteration assumes a totally different form. In this case, no difficulty is experienced with regard to rosinous shellac on account of the strict regulations and severe penalties mentioned above, but complaint is made that a considerable percentage of other impurities is frequently found. There is no doubt that such complaints are well-founded. During the last few years it has been found that molasses, powdered clay, powdered lac refuse, and flour have been mixed with the shellac, and that by the use of unusually porous cloth bags in the melting process a large proportion of the impurities in grain lac ooze out into the refined shellac. The Calcutta shellac contract contains a clause guaranteeing the shellac not to contain more than a certain percentage of *rosin and other impurities,* the penalty being 8 annas per maund for every 1 per cent. up to 4 per cent. above the allowed amount, and Re. 1 per maund for every one per cent. in excess. Shellac has, however, only been tested for rosin, and the guarantee regarding other impurities has hitherto been a dead letter. Recently some firms have attempted to insist upon this clause, but certain others have held back, the custom of the trade being at present in favour of the latter. In such a case, it would undoubtedly be of great benefit to the trade if there were a recognised shellac association which could decide such points as this. If it is clear that it would concern itself only with the policing of the trade, standardization of contracts, arbitration and kindred matters, there is no reason to believe that the formation of such an association would meet with any opposition.

Shellac *versus* seedlac.

The second point which has raised considerable dispute in this country is the form in which the export should be made. It has been urged on more than one occasion, and even in semi-official publications, that there seems to be no reason why so large a proporton of the lac exported should be laboriously converted into shellac instead of being exported as seed-lac, the consumers being themselves able to make any addition required for special purposes. It is argued that a clean grain lac free from dirt should answer the purpose of many consumers better

than shellac. This contention is based upon the following assumptions *viz*, (1) that seedlac is a purer article than shellac, the latter being adulterated by rosin and orpiment, (2) that seedlac would be as suitable to the consumer as shellac and is only not used because it is not known; (3) that seedlac does not "block" in transit. Thus Mr Puran Singh, Chemist to the Forest Research Institute Dehra-Dun, wrote in 1911 "Granlac washed as above is as good as shellac for most industrial purposes It contains 96—98 per cent of resin, no colouring matter and only about 2 per cent. of foreign impurities. The lac consumer has, in many instances, still to be convinced that for his purposes this refined grain lac is as good as his present shellac" All these three claims on behalf of seedlac appear to be mistaken. In the first place, seedlac is the condition of the raw material after washing and before manufacture. It contains many impurities which are left in the bags when the lac is roasted, and all these would be present in the exported seedlac. The assumption that shellac must contain an admixture of rosin is certainly wrong: there may be present a small percentage of natural tree rosin, but this will be equally present in the seedlac and, as has been mentioned above, the further admixture of rosin to lower the melting point is not a necessity of manufacture. The United States of America insists upon receiving pure shell and button lac for all superfine grades. Similarly, the admixture of orpiment is a matter of appearance and is made to give the requisite orange tint. In the finest quality shellac there is practically none (perhaps $\frac{1}{8}$ per cent.), and in button lac none at all. Manufacturers are sometimes asked to add orpiment, which cannot rightly be regarded as an adulterant. The contention that seedlac is purer than shellac, or even as pure as shellac, cannot hold water.

Secondly, it is certainly not the case that the consumer would ordinarily find seedlac suitable for all or most of his purposes, if he knew of it The United States Shellac Importers' Association (which is the largest association of its kind and which represents the interests of the importers of all forms of lac) has given its opinion on this point that seedlac has its purposes but would not substitute for lac in shell form, which for general purposes is superior to the seed form. The London Shellac Association has expressed an identical opinion. Even without this categorical denial of the claim, it

*"Note on the chemistry and trade forms of lac."—Forest Bulletin No. 7, 1911.

would be a very unsafe assumption that the buyers of an article like lac are unaware of the form most suitable for their requirements

Thirdly, it appears to be erroneous to claim that seedlac does not "block" (*i.e.*, coagulate into a solid mass) during transit. The whole weight of the evidence of those persons most concerned with the trade is that seedlac "blocks" as readily as shellac or even more so. Finally, those who urge the superior claims of seedlac as an article of export lose sight of two most important points, *viz.*: (1) that seedlac becomes insoluble very much more readily than either sticklac or shellac (manufacturers therefore ordinarily protect themselves against a loss by converting stick into seedlac only in such quantities as can be immediately converted into shellac) and (2) that a general substitution of seedlac for shellac in the consuming markets would mean the ruin not only of the shellac industry but also of all those industries which rely upon the by-products of shellac (*i.e.*, *kiri*, which is used in the bangle and bracelet-making industries) for their raw material. In view of these facts, the whole question may now be regarded as definitely settled.

Lac dye.

There are a number of other questions connected with the lac industry which cannot be discussed here in detail. For example, the question of the lac dye is of great interest inasmuch as it was originally almost wholly for the production of the dye that lac was collected. In recent years, the export of lac-dyes has disappeared, both on account of the competition of synthetic dye and because of the vastly increased number of uses to which the resin can be put. The dye is still said to be used for artistic rugs and *saris* in certain parts of India in preference to the synthetic article, and if this is so it is certainly regrettable that practically all the lac dye produced is at present thrown away. It has been suggested that the dye liquor might be used as a manure, on account of the rich supply of nitrogen contained in it, but though some attempts have been made to establish this on a commercial basis they have hitherto been unsuccessful. This has apparently been due to the absence of a sufficient quantity of phosphates in the dye-cakes, and it is probable that although the dye liquor may have a high manurial value if run straight on to the fields and allowed to decompose there, the dry dye-cakes have far less value for the purpose.

Lac wax.

Again, there is a certain demand for lac wax, which is said to be of use for boot polishes. The wax is not, however, ordinarily separated from the resin in the manufacture of shellac, and when so separated (as in the spirit process) the value of the resultant lac resin as shellac is said to be inferior. Further investigation of this and kindred questions, however, would very possibly have valuable results, and it cannot be said to be certain that the fullest possible use is yet being made in India of the natural monopoly of the lac industry.

An Argument for a Change in the Lac Industry.

BY W. A. FRAYMOUTH, F.C.S.

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India possesses in her lac, the monopoly of a raw product which may be regarded as essential in the arts and manufactures of Europe and America. The writer knows of the occurrence of lac as far east as the Mekong valley and in Siam, but he has not heard of its occurrence beyond the western confines of India, while the first attempt to introduce it into Ceylon is just being made. It does not occur north of the Himalayas. The largest production is from Chota Nagpur, Central India, the Central Provinces, Sind and Burma.

The lac insect, a small louse (*coccus lacca*), appears embedded in a resinous incrustation on the young twigs of very many species in the forests of India, but for practical purposes, the trees from which it is gathered are :—

Schleichera trijuga : Kusum :—the incrustation is thick and pale yellow in colour. The insect is healthy and strong and may be moved from the Kusam to all other likely species.

Zizyphus xylopyrus : Ghont :—allows a very healthy insect to develop and the young brood spreads both upwards and downwards on the tree. This tree affords the best home for lac from a commercial point of view.

Butea frondosa : Dhak : Palas :—in favourable years, the yield of resin is large, but the brood on this species is very subject to destruction by frost or storm. The resin is darker than that from Kusam or Ghont. The greater part of the lac of India is produced on this tree.

Ficus religiosa : Pipal :—often produces large quantities but the resin is always dark in colour.

Acacia arabica : Babul :—yields large quantities of lac in Sind

Origin and growth of lac.

Twice in each year, the larvae swarm from the body of the mother insect (below the resin) and each little insect at once attaches itself to the nearest favourable spot by inserting its proboscis into the tender bark of a young twig. Drawing its sustenance from the sap below the bark, it starts at once to exude a resinous semi-liquid from under the scale, which slowly wells up all round the growing insect until, with the exception of a breathing tube, (appearing as a white filament above the resin), each insect appears buried in a dome of resin After two or three months, the male insects (some of which are winged) emerge backwards up the breathing passages, crawl over the resin, and enter the female cells. After an activity of about a week the males die and leave the mother insects in their incrustation of resin, which increases then in such quantities that the single domes of resin merge together to one mass, which usually completely envelopes the twig. This is then *sticklac*. The mother insect increases enormously in size after this and is found to contain large quantities of a thick red liquid which eventually granulates to a mass (over 1,000 to each mother) of larvae. At this stage, the outside of the incrustation on the twig shews yellow spots. If the branches be cut now and placed on other trees, a week or so later the new brood will escape and will fasten itself on new branches of the same or another tree. It is possible to move this broodlac great distances.

This cycle is repeated twice in each year, but the time of each swarming differs greatly in different parts of India and Burma. In Central India, the first swarm emerges in mid-July and matures in early November, when it emerges to form the brood which matures in the next July Exceptional divergence from the usual dates has led some investigators to suggest more than two swarms in each year. There are, however, only two swarms. Much has been written about pests destroying the lac, but none of these damage the resin proper and need not be feared from a commercial point of view. Extreme changes in temperature, frost and great heat will destroy a brood and thus cause loss to the lac cultivator. If he avails himself of nature's arrangements to multiply the yield of lac, that is, if he spreads *all broodlac in each crop*, he need not fear the periodic failure of the brood.

It has been customary for centuries for the Indian lac collector to take his crop while the incrustation is soft and wet and before the

larvae escape. The shellac manufacturer and those who wish to melt the resin demand this "green" lac because of the low melting point of the resin in such sticklac, but it is this persistent destruction of the brood which has kept lac as an expensive article of commerce and has led to periodic shortage of supply, thus playing into the hands of those who have used lac as a pawn with which to gamble If the incrustation be left on the trees, or if the twigs covered with lac are cut and moved to other trees at the time of swarming of the larvae, not only can a full yield of resin be obtained, but the cultivator leaves the brood to produce fresh resin. At present, however, the greater bulk of the lac of India is taken before it is mature.

Processes of manufacture.

The collector cuts off the young branches covered with lac and scrapes the incrustation away from the stick. If the larvae have swarmed from such lac, it is possible to obtain a clean lac containing as much as 85 per cent. resin. The usual "sticklac" (free from sticks) which reaches the markets does not contain more than 50 per cent. of resin. Adulteration and weighting with sand and ashes is common at this stage, in spite of the fact that the lac buyer is extremely expert and always discounts moisture, sand, stick and other foreign matter. This does not seem to stop deliberate adulteration, however.

This raw lac is received in the shellac factories of Mirzapur, Purulia or Calcutta and is there crushed in stone "chatkis" or roller mills, great care being taken not to over-crush and so produce dust. The crushed product is known as *katcha chauri*. The evenly-broken grains mixed with immature larvae (lac dye) and other foreign matter, is then mixed with water in a large stone basin. The workman enters the basin and with a special swirling action of the feet, rubs the grains of resin against the rough side of the stone bowl, triturating all soluble and semi-soluble matter away from the resin. A weak alkali is usually added to the water. The water is changed from time to time by decantation, after allowing the grains of resin to settle, and finally the resin is drained in a cloth free from all matter that is carried away by the water. The effluent water used to be settled and the red sludge from the bottom of the settler was pressed into cakes of lac dye. There is no longer any demand for lac dye, for it is of little use except as a dye for woollen fabrics, and cannot in the writer's opinion ever compete with aniline dyes.

After drying in the sun, with extreme care to prevent incipient melting of the grains of lac, the washed *chauri*, still containing some animal residues and particles of stick, is passed to women-workers, who winnow it over straw trays. By two separate jigging motions, all stick and fluff, and again sand are removed, leaving a remarkably clean product (*safa chauri*) consisting of bright and clean grains of resin. Many analyses of this product have shown from 94 per cent. to 96 per cent. of lac soluble in warm alcohol

This "grainlac" or "seedlac" is gradually finding favour with consumers of lac, who formerly used "buttonlac" and "shellac" and consumers in America buy it on an analysis basis, allowing 5 per cent. of insoluble matter but penalising any insoluble matter above this figure.

The shellac manufacturer in Mirzapur or elsewhere does not stop at this product, but continues his process as follows · The clean seedlac, with which some pine rosin and powdered orpiment are usually mixed, is filled into cotton cloth tubes usually about 50 feet in length. The one end of the filled tube is fastened to a small hand windlass which is kept twisting by a woman operator. The other end of the tube is held in the left hand by the *karigar*, the man who melts the lac, who is seated at the far end of a furnace. This consists of a charcoal fire on a hearth, which is domed above to reverberate the heat through an opening running the full length of the front of the furnace, which thus throws its radiant heat on to the tube. The cotton tube filled with lac hangs below this open front of the furnace, being suspended between a peg or hump at the one end of hearth and at the other end of the furnace, from the hand of the *karigar*. There is a clean slab of stone below the tube with a long depression containing water.

Shellac manufacture.

As the tube turns, exposing constantly fresh surfaces to the radiant heat of the furnace, the *karigar* resists the torsion with his left hand. Gradually, the lac in the tube melts and exudes through the pores of the cloth. As soon as the molten resin appears, the *karigar* scrapes it up with an iron spatula, often allowing some to drop on the wet stone below, often dipping the mass on his spatula into the water; and so lathers and mixes the half molten lac and water into a plastic mass. This is again put upon the ever-turning bag and is constantly lathered. During this mixing a relatively high degree of radiant heat (110° C.) reaches the lac, but the presence of water

in the mass keeps the average temperature just below 100° C. The last efforts to mix the melting mass quickly end in a few rapid strokes to gather the "gob" of lac to the spatula and so on to a glazed cylinder (of glazed earthenware or galvanised iron) which stands ready and warm at the *karigar's* side. At once, another workman using a strip of palm leaf in his two hands, pulls the "gob" of plastic lac down over the cylinder, thus producing a skin of lac measuring about 30 inches long by fifteen inches wide. This skin is taken off the cylinder with a skilful jerk, and the stretcher, fixing a toe of each foot in the lower end and holding the top edge in his two hands and mouth, gradually stretches the sheet out to a big skin 5 feet long and 3 feet wide. Throughout this operation, the skin of lac must be kept warm with occasional movements towards the fire which "anneals" the lac and keeps up the plastic condition, which is essential if fine shellac is to result.

The stretched sheets of lac are laid in a heap and when cold and hard, they are broken up and picked over carefully to remove all spots and thick pieces. The result is the shellac of commerce. When no pine rosin has been used, the product is sold as *pure shellac* When the plastic lac is dropped in little lots on to a polished surface, the result is button lac. When dropped on to a plantain stalk, "tongue" lac is the result.

As the melting proceeds, the unmeltable residual matter is pushed along inside the tube, the constant turning gradually squeezing out most of the lac. This residual matter accumulates and must be removed. In order to do this, the *karigar* causes a "kink" to form in the tube beyond the unmeltable residue and thus isolates it from the lac further ahead. After scraping all molten lac off the tube at the top, he stabs the bag and causes the half-molten residue to exude on to the wet stone below. An assistant picks up this black-looking matter and shapes it into a large "plaque." This is then known as "*kiri*." It usually contains about 65 per cent. of lac soluble in warm alcohol.

Considerable quantities of this and other residual matter containing lac were exported to central Europe before the war, where the facilities for use of pure alcohol for industrial purposes permitted the manufacturer of cheap polishes to dissolve the lac in these residues in extractor plants. In some cases, the alcohol was driven off to produce a fairly pale lac, but usually sufficient alcohol was left in to produce in mixture with other resins and dyes,

mahogany French polish. Some of these residues are treated in Calcutta with hot spirit to produce a very dark-red coloured lac called "garnetlac" There are two such works in Calcutta, Messrs. Angelo Brothers, and Galstauns.

The export trade.

Much the greater part of the lac that leaves India is in the form of a dark orange shellac, known as T. N. (originally the mark of a firm called Tularam Naturam), and nearly the whole of this common shellac is made from lac that grows on the *palas* tree. Those who deal in lac in London standardise a sample each year, representing the average quality of the lots of common shellac which arrive from India. Quotations of the price of lac are made on this T. N. basis, both in London and in Calcutta, and there are many speculators who gamble on the T. N. quotation in both markets. The original cause of the great fluctuations in price of shellac are the periodic failures of the lac crop which are so intensified by the collection of lac before the young insect gets a chance to propagate a new brood. Yet there have been years when the amount of lac exported from India was too much for current consumption, *e.g.*, 322,000 cases in 1909; but it is likely that while the world would not buy all this lac at the relatively high prices, which lac has been sold for many years (from 60*s*. to 100*s*. per cwt.), yet if clean lac were offered from India at lower, and above all, steady prices, there would probably always be a demand for this useful resin. We might even hope to find an outlet for double the quantity of the 1908-09 crops which may be estimated at about a million maunds of clean raw lac. It is certain that many manufacturers refrain from beginning to use shellac when it is relatively cheap, because of the ever present fear of a sudden rise in price. During the year 1903-04, the price of shellac rose to 230*s*. per cwt., and the stocks of London dropped as low as 12,000 chests, while the excessive production of 1908-09 reduced the price to 60*s*. and left 100,000 chests in stock in London in 1911. Quite exceptional prices were reached during the war, even 400*s*. per cwt., being exceeded.

Several very complete chemical examinations have been made of lac by Farnar, Hooper and others and it is known that the ordinary lac of sticklac consists of (*a*) two resinous substances, one being insoluble, while the other is soluble in ether, (*b*) a wax, (*c*) a colouring matter named Erythrolaccin, and (*d*) water.

Many exhaustive researches have been conducted with a view to producing a substitute for lac but with no success. The consumer will always buy pure lac, if he can get it at a low and steady price. Thus it does not appear probable that any artificial substitute will ever displace lac in the arts and manufactures of the world, so long as pure lac is offered in Europe at or below 60*s*. per cwt.

When the consumer abroad takes lac as shellac or button lac or grainlac into his works, in nearly every case, he makes a solution of lac either in alcohol (for wood polishes, metal lacquers, the lining of a shell, etc.); or in borax (for the stiffening of felt hats and similar uses), or in soda ash and water (for the preparation of *white lac*). Thus, directly it is taken into use, it does not matter in the slightest what the original form may have been. Shellac in flakes will dissolve a trifle quicker than button lac, and grainlac shews a trifle more insoluble matter, but as most shellac contains even up to 3 per cent. impurities, the careful manufacturer must filter his solution of lac in any case. The extra impurities in grainlac have been allowed for in the purchase price, but on the other hand, a simple inspection of grainlac is sufficient to make sure that it contains no pine rosin or other foreign resin, and so there is every inducement to the consumer abroad to buy grainlac instead of shellac

There are exceptional uses for lac, where a very pure and spotless shellac or button lac is required, for instance in the manufacture of gramophone records or other "vulcanite" mixtures, and here some shellac will always be required.

For the manufacture of white lac, the plain washed grainlac is particularly suitable. After solution in soda ash and water, the solution is filtered and the filtrate is bleached by the addition of chlorine water. The wax in the lac precipitates during the bleaching, and can be filtered off or left in the brew. To reach the exact point, where the solution has had just enough of chlorine and no more requires great skill. The bleacher then adds hydrochloric acid slowly to the brew which precipitates a white cloud of bleached lac. On raising the temperature, the bleached lac coagulates and can be lifted out of the solution and washed, worked up to big "hanks" of a material (exactly like white "Edinburgh Rock") which is soluble in alcohol to yield a pale transparent polish. A very large amount of the lac in India is converted into white lac abroad. It is unlikely that white lac will ever be manufactured in India.

because it remains hard only at low temperatures. It is an additive compound of lac and chlorine and it rapidly deteriorates with heat. It is stored and moved in barrels of water in Europe. Lately, American manufacturers have washed and dried the first precipitate, thus supplying white lac in a powdered form.

Under the circumstances that clean washed grainlac can be cultivated, collected, cleaned, and refined, and landed in London at under 40*s*. per cwt., after leaving good profits in the hands of forest owners, collectors and manufacturers, while it is impossible to land shellac or the melted forms in Europe at less than 55*s*. (if the forest owners, collector and manufacturer are to make any profit), it is to be seriously considered whether it would not be better for those interested in lac in India to aim to produce large quantities of refined but not melted lac, at a regular low price than to work as they do. There is little doubt that such a policy would eliminate the gambling element in the lac trade and thus make it safer for the Indian industrialist.

Standard Lac Products.

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Present state of lac industry.

As explained in the foregoing articles, stick lac as it occurs in the forest consists of three main constituents; lac resin, the outermost portion of the incrustation, lac wax, immediately surrounding the body of the lac insect, and lac dye mainly present in the body of the insect itself. By the indigenous methods of manufacture, lac is produced containing undefined percentages of wax and added rosin; the wax is not separately recovered at all, and the dye, if it is recovered, is sold in cakes containing an indefinite percentage of dye mixed with wax, impure resin, organic matter derived from insect bodies and ordinary dirt.

Special products needed for special uses.

The best brands of shellac have a fairly constant composition, but they are not prepared with any special knowledge of, or regard for, particular trade requirements. The hatting trade, *e.g.*, requires lac containing a certain known percentage of rosin and wax in order to obtain the necessary pliability. Different kinds of hats in fact require different mixtures. A different quality again is required for gramophone records, while for varnish, freedom from colour is in many cases essential. For lacquering metals and French polishing wood, pure lac-varnish containing no added rosin is best adapted. For sealing wax and the coloured lacs used for toys and various forms of art work, special material is again required. It is evident, therefore, that the line of development in the lac industry lies in the direction of standardisation.

The colouring matter of lac and its removal.

One of the first difficulties in obtaining satisfactory lac of standard quality, especially for varnishes, is the elimination of colouring matter which tends to darken the lac. The colouring matter in crude stick lac is present, broadly speaking, in three conditions; as water-soluble dye, which can be extracted by ordinary washing especially in

slightly alkaline solutions; as a lake or organic compound practically insoluble in water and alcohol and only partly soluble in weak alkali, and as a colouring matter in the lac-resin itself, also insoluble in water and weak alkali, but soluble in alcohol. Strong alkali of course will attack the lac resin. It may not be generally known that the only practicable method, apart from bleaching, so far used for removing this colour from lac resin, is the method actually employed by the indigenous worker, *viz*, melting with sulphide of arsenic There is no doubt that a definite reaction takes place resulting in the elimination of the colour and the best brands of shellac, *e.g*, D C, owe their freedom from colour to this process Once the lac is made into varnish, it is exceedingly difficult to remove this colour by any practicable chemical process. In order to produce colour-free varnish from seed lac, therefore, without recourse to the method of melting with orpiment, actual bleaching with hypochlorite, as described in the article by Mr. Fraymouth, would appear to be necessary, though, where expense is a secondary consideration, direct treatment of the varnish by various precipitants is

The production of special lac mixtures.

For every other purpose except the production of pale varnishes, the colour still present in well washed seed lac is of no moment. What is important is the percentage of resin and wax, which should at any rate be definite and constant for any given purpose as explained above This constancy of composition can only be attained with exactitude by means of solvent processes. By cold solution in alcohol the lac can be separated from the wax, and from the residue after cold treatment with alcohol the wax can be extracted with hot alcohol and added along with resin in any desired proportion to the main alcoholic solution of lac. From the varnish thus obtained of the required composition, the alcohol can be distilled off and the residual lac prepared in a suitable form for market. The above process, though apparently simple, requires special equipment and scientific supervision, as the manipulation of lac in bulk is by no means easy, and mistakes may easily be made resulting in intractable masses of infusible burnt resin.

Soft lac.

An important possibility is the production of soft lac in bulk for certain processes in the hatting and felting industries This material which is obtained by treatment of lac with alkali under certain conditions can be made of

any degree of pliability and is very useful as a basis for felting for soft hats, slipper soles, etc.

Lac dye.

From the crude cake dye sold in the bazaar at an anna or two per pound, it is possible by simple methods to obtain a second grade lac varnish, a satisfactory lac wax which has similar properties, and would have similar value, to bees wax, and a preparation of lac dye of approximately constant composition. Lac dye is one of the fastest and brightest reds for dyeing silk and wool, and by suitable mordants it can be made to give a pleasing pink shade to cotton. If supplied in a reasonably pure state, it should therefore find considerable application. The crude cake dye is at present practically a waste product Its scientific treatment with a yield of three valuable products is likely, therefore, to be an immediately profitable undertaking.

Future development of the lac industry.

The working up of seed lac into standard products needs larger capital than is required for dealing with crude lac dye, and its financial success depends to a great extent on the establishing of shellac prices which at present are liable to great variation. The cause of this is to be found partly in the present conditions under which lac is produced, as described by Mr. Fraymouth, and partly in speculative holding of stock. If the first cause could be eliminated by more scientific methods of cultivation, there would be less inducement for the second to operate, and India, with the raw material in the country and with cheap alcohol in unlimited amounts, could by intelligent co-operation with consumers hold practically a monopoly of an increasingly valuable staple product.

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The Glue and Gelatine Industry.

By Gilbert J. Fowler, D.Sc., F.I.C.
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The glue and gelatine industry is really bound up with the production of bone manure, these products being related as follows :—

Glue and its related products.

Glue is obtained by boiling bones with water under pressure, after removing the fat. The resulting liquor is clarified and evaporated. *Size* is liquid or semi-solid glue. *Gelatine* is a refined form of glue and is best obtained from sinews (or from bones from which the mineral matter has been separated by acids) by treatment with lime, washing, bleaching with sulphurous acid, steaming, clarifying and evaporating. *Bone meal* is obtained by grinding the residual bones after extracting the glue, and consists mainly of phosphate of lime, which may be sold direct as a manure or converted into superphosphate by treatment with sulphuric acid.

Prospects of manufacture.

All these operations may be carried on in one large works. Raw material for glue and gelatine exists in large quantities in India. The number of animals which die or are slaughtered annually is enormous. Besides bones and their associated sinews other possible sources of glue and gelatine exist in India, particularly scrappings and cuttings from hides which are at present largely a waste product of tanneries.

Before the war, however, by far the larger part of the bone meal, from which no attempt had been made to produce glue or gelatine, went to Hamburg, where it was sold as a fertiliser. Liverpool and Hull were importing a coarser meal which was used in the manufacture of superphosphates. Crushed bone went to Antwerp and Marseilles where it was used in the manufacture of bone black, buttons, handles, etc. The sinews, which are specially suited for the manufacture of gelatine, were all exported to Hamburg. It is evident, therefore, that great possibilities exist for making valuable

by-products from these sources, if they were worked up in this country. While it is doubtful whether the bones of Indian cattle contain enough fat to pay for recovery, the production of gelatine from sinews offers large possibilities of profit and, if the bone meal can be disposed of at a fair price, the extraction of glue should also be profitable.

Apart from fat extraction, it may be taken that plant and buildings to deal with 10 tons of bones and associated sinews per day would probably cost about 3 to 4 lakhs of rupees. The main essential in obtaining good glue and gelatine is scrupulous cleanliness in all the processes involved. Owing to climatic conditions, it is probable that almost anywhere in India special equipment will be necessary at certain seasons for the final evaporation and drying off of the glue and gelatine, but there is no inherent difficulty in providing this.

Markets for glue, etc.

As regards the resultant bone meal, there is likely to be some outlet in India in Bengal, Madras and Ceylon for the tea and coffee plantations. The accompanying tabular statements indicate that considerable quantities of artificial manures are imported into these parts, and during the war bone meal from India has been taken by the planters. The extraction of glue would certainly depreciate the value of the bone meal, but not to such an extent as to render the process uneconomical.

Although there is not at present any great demand for superphosphates in this country, the experiments of the agricultural departments have proved that, in Northern India at any rate, the application of this manure to the soil would have a very marked effect, since the available phosphates in large areas of the Gangetic delta are almost entirely exhausted. If, therefore, it can be placed on the market in large quantities at a reasonable price, it is almost certain that the demand for it will in time become very great. The dominating factor in its production is the cost of sulphuric acid; and if this is available at low rates in the near future (see page 61), the manufacture of superphosphates from bone meal should be a paying proposition, while the finding of a local market for this by-product should greatly assist the development of glue and gelatine manufacture in India. Superphosphates thus made, however, will have to compete with those extracted from the mineral apatite, for the production of which a company has already commenced operations near the Tata Iron and Steel Works, Sakchi.

The following tables of imports of artificial and mineral manures and exports of bones will serve to amplify the foregoing short statement :—

TABLE 1.—*Imports of artificial and mineral manures into India since 1913*

Countries of origin.	1913-14.	1914-15.	1915-16	1916-17.	1917-18
	Tons.	Tons.	Tons	Tons.	Tons.
United Kingdom . .	1,500	1,027	1,910	1,290	90
Germany	3,757	444	106	31	..
Belgium . . .	2,662	995	..	..	..
Japan	40	60	1,583	1,558	705
Share of Bengal. . .	2,739	1,886	3,852	3,340	1,094
" Bombay . .	49	97	103	61	..
" Sind . . .	2	1	4	.	..
" Madras . .	5,260	1,417	1,007	1,020	700
" Burma. . .	175	70	50	60	40
TOTAL (INCLUDING OTHER COUNTRIES.)	8,234	3,471	5,106	4,481	1,834

TABLE 2.—*Exports of bones from India since 1913.*

Countries of final destination.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	Tons.	Tons.	Tons.	Tons.	Tons.
United Kingdom . .	14,014	11,095	15,170	9,201	50
Ceylon	5,139	6,028	9,597	11,605	7,342
New Zealand . . .	2,055	1,975	6,115	9,250	6,951
Germany	11,131	3,461	..	..	..
Belgium	34,320	13,655	..	..	..
France	16,170	10,065	4,088	3,100	525
Japan	11,237	6,787	3,400	5,450	5,380
United States of America.—					
Atlantic Coast . . .	3,273	5,093	4,065	2,050	..
Pacific Coast . .	4,880	4,369	6,108	200	..
TOTAL (INCLUDING OTHER COUNTRIES)	105,413	63,975	50,636	42,042	20,479

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Industrial Alcohol.

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While India possesses in abundance many important raw materials for industry, she is relatively poor in sources of power of the more ordinary description. Her coalfields are not widely distributed and the quality of the coal available is not of the highest. Water power like coal is confined to certain centres. Petrol, kerosine and oil fuel generally have to be imported. The production of charcoal involves the destruction of slow growing forests. There is one form of fuel, however, which can be obtained in unlimited quantities, *viz.*, "alcohol," chemically known as ethyl alcohol, C_2H_5OH.

Sources of alcohol.

The great chemical family of the carbohydrates (so called from the fact that its members are composed of carbon, hydrogen and oxygen, the last two elements united in the proportion to form water) includes such universal plant constituents as cellulose and starch, as well as the numerous naturally occurring sugars. Most of these naturally occurring sugars can be fermented by yeast, yielding alcohol and carbon dioxide, or carbonic acid gas as it is popularly termed. The celluloses and starches are not directly fermentable by yeast, but by suitable chemical means they can be readily converted in many cases into fermentable sugar.

The production of carbohydrates, whether cellulose, starch or sugar, takes place under the stimulus of solar energy. Alcohol, therefore, as it is derived from carbohydrate material, affords a means of utilising present solar energy, as distinguished from the use of coal which utilises the solar energy of past ages. There is, therefore, practically no limit to its technical production and India with its superabundant sunshine is especially suited for such an industry.

Apart from its use as fuel, alcohol has innumerable other applications of equal or greater importance in industry Alcohol thus produced for industrial, as distinguished from drinking purposes, is termed industrial alcohol or sometimes 'denatured' alcohol, from the fact that some substance has been added to it to 'denature' it or make it unfit to drink.

The sources of alcohol in India, the methods of its manufacture, and its industrial uses may now be considered more in detail. India unfortunately actually needs to import cane-sugar owing to the present condition of the indigenous sugar-cane industry When cane-sugar is used as a source of alcohol in India, it is usually imported in the form of molasses from Java.

Alcohol yielding materials: cane-sugar.

In the flowers of the *mahua* tree (*Bassia latifolia*), there is an enormous source of alcohol production. These flowers, which are of a waxy whiteness when fresh, contain anything from 40 to 60 per cent. of fermentable sugar, mainly in the form of what is known as invert sugar, though under certain circumstances a considerable proportion of cane-sugar is also present. The possibilities of this source of alcohol may be gathered from the fact that the Hyderabad distilleries alone are capable of producing 10,000 gallons a day of alcohol from *mahua*, or one-third more than the whole consumption of light petrol in India.

Mahua sugar.

All cereal grains contain starch, which serves as food for the seedling plant. In the course of germination of the seed the starch is converted into sugar which can be assimilated as food by the plant. It is this sugar which is fermentable to alcohol by means of yeast. Before starch-containing grains can be used for the production of alcohol, they have as a rule to undergo the process of malting. This consists in the encouragement of incipient germination which is arrested by heat as soon as the most favourable stage has been reached. In certain cases, malting may be dispensed with and the conversion of starch into sugar brought about directly by heating with acids or by the action of certain moulds.

Cereals.

Many plants contain their store of starch food in the so-called rhizome or in tubers attached to the root system. Such plants are the cassava, the source of arrowroot, artichokes, potatoes and other

Starch-containing tubers.

plants known to botanists, some at present looked upon as weeds, but which grow rapidly under favourable conditions. Potatoes have not proved as cheap a source of alcohol in the United States as either sugar or grain, and while cassava is considered by some as an exceptionally cheap source of starch, and therefore of alcohol, agricultural opinion in India does not seem to favour it, though trials with sweet potatoes have been suggested.

Sawdust.

Certain woods on treatment with sulphurous acid under pressure yield fermentable sugar and where large quantities of waste sawdust are for disposal its treatment in this way may be economical. The treatment of "megasse" (the residual cane left after the pressing out of cane-sugar) by this process is worth consideration.

All things considered, the *mahua* flower would seem to be the best raw material for industrial alcohol in India.

The production of alcohol from sugar.

From the sugar solution prepared from any of the above sources, alcohol is obtained by introducing yeast under suitable conditions, allowing the fermentation to proceed to its limit and then distilling off the alcohol. Yeast is a microscopic organism consisting of single round or pear-shaped cells, which are capable of rapid reproduction by budding when placed in a suitable medium. There are many varieties of yeast. Natural or wild yeast, which occurs wherever there is fermentable sugar, *e.g.*, on the *mahua* flower or on the skins of fruits, is a mixture of several species not all of which are capable of giving high yields of alcohol. It has been found by experiment that the best results are obtained by introducing pure selected cultures of yeast into sugar solutions which have been previously sterilised. The addition of nitrogenous food in the form of 'spent wash' from previous operations and of certain other food materials, such as phosphates, have been found to have a beneficial effect in increasing the yield, as compared with the more or less empirical methods at present employed. It remains of course to be seen how far the increased yield obtained by scientific working will pay for the additional cost involved. Probably it will be more satisfactory to erect up-to-date plant than to attempt to remodel the old.

Besides the fermentation process, the method of distillation ployed makes a considerable difference to the strength and ntity of alcohol produced, and, in modern plants, stills operated the continuous principle are alone used. In these stills, of

which the Coffey still patented in 1832 is the type, a descending stream of alcoholic wash is heated by an ascending current of steam, and alcohol is thus continually distilled off By developments of this principle it is possible readily to obtain alcohol of 95 per cent. strength.

Industrial uses of alcohol: fuel.

In suitably constructed internal combustion engines, alcohol has shown itself an excellent source of power. It differs from petrol in requiring a higher compression to obtain the same efficiency on explosion. Nevertheless, when mixed with a small percentage of petrol and about 30 per cent. of ether, it has been found quite a practicable fuel for ordinary motor cars without any modification of design. It can, therefore, well serve as a substitute for petrol in case of shortage of the latter, or at any rate its availability may prevent too great a rise in the price of petrol.

Apart from motor car traffic altogether, alcohol fuel has many possible applications, particularly for small stationery engines and for motor boats. In these two cases, that of motor boats particularly, the greatly lessened danger from fire in the case of alcohol, as compared with petrol, is a great advantage in favour of the former. The alcohol flame can be readily extinguished by water which only tends to spread the flames of burning petrol. As household fuel for cooking, a very large consumption may be predicted, if large quantities are everywhere cheaply available, as it is clean and odourless. This may react in favour of agriculture by lessening the necessity of using cowdung as fuel.

Other uses.

In addition to its use as a household fuel, alcohol can also be used as an illuminant in lamps of special design, with incandescent mantles, or by solution in the alcohol of some substance such as camphor, which will give a luminous flame. In the volume on industrial alcohol by McIntosh, on pages 213-217, some 500 applications of alcohol in various arts and manufactures are given of which the following may be mentioned: the manufacture of acetic acid, acetates, perfumes, tinctures, varnishes and polishes, ether, chloroform, dyes transparent soaps and artificial silk.

Denaturing alcohol.

Pure ethyl alcohol can only be used by special Government permit granted in the case of special use where purity is essential. In most cases, denaturant has to be added to render it non-potable. The substance

mainly used for this purpose are wood spirit or methyl alcohol pyridine, and in India particularly, an objectionably smelling product of the distillation of rubber, known as caoutchoucine. Special denaturing agents are often used for special purposes, and the problem of preventing illicit consumption of alcohol without interfering with its economic uses in industry is a somewhat difficult one.

Books of reference:

"Industrial Alcohol"—McIntosh (Scott, Greenwood & Co., London).

"Denatured or Industrial Alcohol" (Wiley & Sons, New York).

Medical and Surgical Requirements, their Manufacture in India.

By Lieut.-Col. H. Ross, O.B E , I.M S.,
Assistant Director General, Indian Medical Service (Stores).

The strain of war has led to a great development in the utilization of Indian resources in the provision of drugs, medicines, and other materials, not only to meet the requirements of hospitals in India, both military and civil, but also for overseas forces. It was recognised that many articles formerly imported could, and should, be manufactured in India.

Additional analytical chemists are now working at the manufacturing Medical Store depôts at Madras Bombay and Lahore and many preparations are being manufactured at these depôts from indigenous raw materials which were before the war imported from Home. In order to relieve, as far as possible, the strain on Home resources and to economise in freight, every effort has been made to develop the manufacture of surgical dressings at the depôts, and, at the same time, to encourage reliable private firms to extend their output in this direction. These efforts have been most successful and have undoubtedly effected a considerable saving to Government especially in the local purchase of cotton wool, gauze, lint, etc., the prices of which in the English market have advanced roughly 400 per cent. since 1914.

The absolute necessity of securing the correct percentage of medication and complete sterilization makes it essential that orders for the manufacture of these articles should only be placed with firms whose reliability has been fully ascertained. Private enterprise is now largely responsible for the supply of absorbent cotton of good qualty, lint, gauze, and, in addition, it has been utilized in supplementing the supply of medicated and compressed dressings.

Prior to the outbreak of war, the Medical Stores Department was manufacturing pharmaceutical preparations on a considerable

scale and the fact that it was in a position to do so has been of material assistance in meeting the greatly increased demands.

Medical Instruments, etc.

The Indian Medical Stores Department is a very large purchaser of surgical instruments and appliances, of which an important source of supply for many years, has been the workshops at the Medical Stores Depôt, Bombay. Part of these premises has been handed over to a private concern, which has established in it a factory that provides a considerable portion of the requirements of the department. It employs several hundred workmen who have been trained to manufacture and repair instruments and appliances, and the articles turned out are of excellent workmanship and finish, comparing favourably with articles manufactured by the best known surgical instrument makers at Home. War demands have led to many new developments including the manufacture of shaped artificial limbs and orthopaedic appliances, and all the artificial limbs supplied to the wounded returning from overseas have been manufactured in this factory.

Glassware.

The possibility of obtaining supplies of Indian-made glassware for laboratories was considered at an early stage, and in 1917 such articles as petri dishes, litre flasks, glass tubing and test tubes of reasonably good quality were obtained from the Upper India Glass Works, Ambala City. As the Director General of the Indian Medical Service imports large quantities of different descriptions of glassware, he suggested in September 1917 that the question of glass manufacture in India should be taken up. In this direction much has been done, with the assistance of the Munitions Board, and considerable orders have been, and are now being, placed with several manufacturing firms in India. Among these are :—

The Upper India Glass Works, Ambala.
Bijhoi Glass Works, Moradabad.
Allahabad Glass Works, Naini, and the
Scientific Instrument Company, Allahabad.

There is little doubt that every encouragement should be given to firms in India who are willing to undertake the manufacture of glassware, and eventually, it is hoped, that most of our requirements in this direction will be manufactured in India.

Rubber goods and enamelled iron.

The Medical Stores Department imports large quantities of various rubber goods and owing to their perishable nature a considerable loss is incurred Endeavours are being made to arrange for the manufacture of as many of these as possible, and a large range of samples have been sent to the Colombo Rubber Mills a firm of rubber manufacturers lately established in Ceylon. A great number of enamelled iron articles is also consumed, and samples have been submitted to Messrs. Heatley Gresham & Co., Calcutta, who are undertaking the manufacture as soon as the necessary machinery is obtained from Home.

Manufacture of drugs in India.

The question of ascertaining what raw materials are, or can be made, available in India and the best method of obtaining supplies, both for immediate requirements and with a view to future developments has been a subject of close investigation for some time. It is an undoubted fact that, up to now, the indigenous resources of India have not been utilized to anything like the extent possible. The practice, prior to the outbreak of war, was to purchase in England through the medium of the India Office not only manufactured drugs, but also most of the raw materials required for the manufacture of pharmaceutical products, for most of which the raw materials had actually been exported to England from India. For instance, sandal-wood was exported as wood and returned in the form of oil; whereas arrangements have now been made to manufacture our total requirements of sandal-wood oil at the Medical Store depôts. Again myrobalans sent Home returned as tannic acid while we now manufacture all our requirements.

Nux vomica beans were sent to England and returned as the powder and extract, and in the form of strychnine, but we are now manufacturing all our requirements of the two former and the chemists at the Medical Store depôts are investigating the possibility of the manufacture of strychnine from *nux vomica* beans. Potash salts existing in India were never utilized in making potassium carbonate, bicarbonate, acetate, citrate, cyanide, red and yellow prussiate, etc. All these are now being made by private firms in India. *Ajwan* seeds were formerly exported to Germany and returned to India as thymol. We now manufacture our total requirements and several firms are manufacturing thymol of good quality on a large scale. These firms should be assisted

to get in touch with buyers in England, as there are great possibilities of a lucrative export trade with England

A general investigation as to the possibilities of obtaining Indian grown products has for some time been going on, and in December 1917, the Director General drew up a note pointing out the desirability of taking up the question of the cultivation of medical trees and plants. This has led to the proposal that a committee should be formed to deal with the subject. So far, the information available merely touches the fringe of possibilities and, owing to the almost complete lack of data in the form of any up-to-date literature and reliable information on the subject, the problem is an extremely difficult one. Many of the medicinal plants required grow wild in Indian forests, and owing to the hitherto small demands, are classified as minor forest produce. No special attention appears to have been paid to them nor does there exist, as far as is known, any effective organization for collection. In the first place, it would appear desirable that a survey should be undertaken to ascertain what medicinal plants grow wild in the forests, and where such plants grow most freely, and are most accessible for collection. Such a survey would assist in supplying Government's requirements and those of private firms, possibly creating a lucrative export trade in the future. This undertaking could only be carried out thoroughly by the Forest Department and the Botanical Survey.

Articles such as cinnamon, cloves, senna, castor oil seeds and various others of every day consumption known to grow and be available in large quantities in India, need not be considered. Our efforts have been concentrated chiefly in the direction of obtaining satisfactory and regular supplies to meet our own requirements, but enquiries have opened up the larger question of the possibility of creating a considerable and valuable export trade from India, thereby assisting in making the Empire self-supporting as regards a number of products formerly obtained from enemy countries.

There can be little doubt that markets would be available, as private firms in India have been, and are now, exporting to Great Britain, America, and other countries Indian-grown drugs, which these countries formerly obtained elsewhere. The demand exists and the problem to be overcome is mainly that of organizing cultivation and collection, but also the reduction of railway freights on such products over long distances, the latter as a temporary measure

until information is obtainable as to what rail tariffs such products can reasonably bear, to allow competition with other sources of supply outside India. The high rail freights from sources of supply to seaports and manufacturing centres in India, permitted Germany and other producing countries, in many instances, to cultivate, collect, ship to London, and re-ship to India at prices, which are actually lower than those at which indigenous products could be made available at Indian seaports.

An example of this is the case of belladonna. This root was grown in Germany, collected, dried, packed, shipped to London, paying one or two middlemen's profits there, re-shipped to India, duty paid on entry, and purchased in India at Rs 40 per cwt. The cost of collection, royalty (in the case of private firms) and rail freights to Calcutta or Bombay, made it impossible for Indian-grown belladonna to compete. In 1916, a communication was received from the Secretary of State that India's demands for belladonna could not be complied with. Upon this, communication was opened with the Superintendent of the Government Gardens at Kumaun and he was asked to lay down five acres under belladonna cultivation, the resulting crop being ear-marked to meet the requirements of the Director General. His total requirements of both belladonna roots and leaves of most excellent quality have since been obtained from this source and although the purchases were made considerably under the ruling market rates, the cultivation has proved a very profitable undertaking.

Again in the case of digitalis our total requirements have been met from Bengal, and the Kumaun Gardens have been asked to place a sufficient area under cultivation to enable them to meet our future demands.

Various other valuable medicinal plants are known to grow wild in large quantities in the Indian forests, but until an organised survey is undertaken, the problem of collection and utilization of these products cannot be satisfactorily solved. A large number of articles which were, prior to the war, imported, are now either being manufactured at the Medical Store depôts, or experiments as to the possibility of manufacture have been undertaken. For instance, we manufacture our total requirements of—

(1) absolute alcohol from rectified spirit;
(2) amylum, B. P. (starch) from rice;
(3) all belladonna preparations from Indian-grown belladonna;

(4) digitalis preparations from Indian leaves;
(5) lysol from saponified cresol;
(6) ferrous sulphate from iron filings and sulphuric acid;
(7) thymol, B. P. from *ajwan* seeds;
(8) nux vomica preparations from Indian seeds;
(9) tannic acid from myrobalans;
(10) silver nitrate sticks from Indian made silver nitrate crystals;
(11) various mercurial B. P preparations;
(12) oxymel scillae, B P. from honey and squills—the latter being obtained from the beach at Salsette outside Bombay;
(13) chaulmoogra oil;
(14) collodium flexile;
(15) sodium sulphate anhydrous;
(16) aloe, B.P.;
(17) calcium carbonate precipitated;
(18) the extracts of cascara, colocynth, glycerrhiza, hyoscyami, belladonna, nux vomica, gentian;
(19) glucose from starch;
(20) essential oils: Anethi, aniseed, cloves, cinnamon, croton, myristica;
(21) iodine powder;
(22) bismuth and ammonium citrate solutions;
(23) magnesium carbonate,
(24) oleic acid;
(25) pyroxylline;
(26) sodium nitrite;
(27) sodium sulphate;
(28) sodium chloride pure;
(29) syrupus ferri phosphatis Co.;
(30) acid sulphuric normal solution;
(31) rectified alcohol,
(32) cedar wood oil.

All the above are new preparations which were formerly imported. In addition to these, the chemists have succeeded in making anæsthetic æther, B. P., of which it is hoped to make our total requirements when its keeping properties have been tested, and boric acid from crude borax. The manufacture of the latter will not pay commercially, until the crude borax coming into India

from Nepal and Thibet is either subject to a considerably lower tariff to make it available at the sea-ports at a much cheaper rate or something in the way of a small factory is started in the Himalayas at some such place as Kotgarh in the Simla hills. Large quantities of crude borax, in transit to India from Thibet, pass through Kotgarh and the refining of crude borax is an extremely simple process which does not necessitate the provision of any special machinery. At present the crude borax which is carried to Bombay, Madras and Calcutta contains roughly 30 per cent. impurities which could readily be extracted.

Experiments are also being made with the manufacture of the alkaloids, atropine, emetine and strychnine, calcium chloride, magnesia, potassii acetas, potassii permanganas, soft and hard soap, refined glycerine, as well as the manufacture of an insect powder as effective as the well known Keating's powder.

The depôts are now making all the pharmaceutical preparations required, including tablets, pills, extracts, tinctures, liniments, liquors, unguents, powders, etc., many of which are new preparations formerly imported of which we have lately undertaken the manufacture. It is not feasible in this note to give full details of everything which is being manufactured but among these are included Codeine tablets, borated talc powder, carron oil, and medicated vaseline.

The Medical Stores depôts are also manufacturing all Government's requirements of castor oil, and arachis oil from Indian-grown seeds. Oxygen is compressed in cylinders for issue to hospitals. At Madras first field dressings are being made for the use of the army at the rate of 1,000 per diem. The Indian Institute of Science at Bangalore supplies ethyl chloride, calcium chloride, calcium lactate, sodium acetate, aniline oil, and lactose.

Bandages are obtained from Indian jails, absorbent cotton wool from Messrs. Sassoon & Co., Bombay, and Messrs. Andrew Yule & Co., Calcutta, and cottons and gauzes, medicated and compressed, from private firms in India. Oil of turpentine and resin are supplied by the Forest Department, and liquor ammonia fortis, lycopodium, acid sulphuric, B.P., acid hydrochloric, B.P., acid nitric, B. P., and the various medicinal potash salts from private firms in India which manufacture them.

Operation room furniture, water bottles, brass pestles and mortars, basins, aluminium measures, formerly imported, are now obtained

from manufacturing firms in India. Trial orders for various description of surgical instruments have also been placed with Indian firms.

Although during the war, it was essential that Government's requirements should, as far as possible, be manufactured departmentally, it will be necessary to consider whether the Government Medical Stores Department should continue to manufacture articles, which reliable private firms are also manufacturing in sufficient quantities in India from Indian raw materials. It is unfortunately true that in India up to now the difference between samples submitted and actual supplies subsequently delivered is liable to be considerable, and until trial orders have been placed and deliveries have proved up to the standard required, it has been, and will be, very necessary to exercise the greatest caution, placing orders only with firms whose reliability is assured. Another difficulty experienced, more particularly with the smaller firms is that, in their anxiety to obtain contracts, they undertake more than they can safely guarantee and break down as regards delivery within the contract period. They are also prone to quote terms which in practice they are unable to carry out, without either suffering heavy loss, or being forced to ask for a revision of rates owing to fluctuations in the markets.

In dealing with the purchase of drugs, surgical dressings and instruments, the question of quality is so important that the best policy is not to place reliance on doubtful sources of supplies. It is essential, therefore, not to discontinue any manufactures until the output by reliable commercial firms has been established on a sufficiently large scale to render it absolutely certain that Government will be able to obtain all its requirements without difficulty and at prices comparing favourably with its own production costs.

Jute, Sann Hemp and Flax.

By R. S. Finlow, *Fibre Expert to the Government of Bengal*, and D. B. Meek, *Assistant Controller of Munitions, Bengal.*

I.—Jute.

The modern Indian jute industry is essentially a development of the last 80 or 90 years, *i.e.*, since the year 1828. Even before that time jute was grown over almost as wide a tract as it is to-day; but the actual acreage devoted to the crop was far less. For instance, the district of Rangpur grew about 20,000 acres of jute in 1803, whereas it has had as much as 250,000 acres in recent years. The same applies to other parts of the jute-growing tract.

Expansion of the jute trade.

Before about 1828, the whole of the jute fibre produced in India was manufactured locally by hand into numerous articles, including clothing; and any export was confined to hand-made products, such as gunnies. In 1828, the first export of raw jute to Europe was made, but although the production and also the export, of jute increased with some regularity, it was during the Crimean and American Civil wars, the first of which shut off Russian flax and hemp, and the latter American cotton, that jute began to be used on a really large scale. Since then it has never looked back. The following statistics * represent the great increase in the production of jute since 1874 :—

* (Supplied by the Director of Statistics.)

TABLE 1.—*Increase in the production of jute since 1874.*

Year	Area under jute	Produce [lakhs of bales of 400 lbs.]	Approximate value [lakhs of rupees.]
	Acres.	Bales	Rs.
1874	..*	27,00,000	5,40
1902	2,142,700	66,00,000	18,00†
1909	2,876,400	90,00,000	30,00†
1914	3,358,700	105,00,000	50,00†

* Accurate figures not available.
† Rs. 15 = £1.

Thus the yield of fibre has increased by 300 per cent. in 40 years. In 1851, the value of the exports of raw and hand-manufactured jute from India was about 40 lakhs of rupees, and the price of fibre was from Re. 1 to Rs. 3 per maund. In 1914, the value of the raw fibre produced was about 50 crores and the price of fibre was from Rs. 7 to Rs. 12 per maund. As the bulk of this sum goes annually into the pocket of the Bengal cultivator, it is easy to understand why he is the richest of his class in India.

After the commencement of the war, a very big crop, coinciding with the shutting off to a large extent of the export of the raw fibre, caused a heavy slump in the price of the latter, and the area devoted to the production of jute fell by 30 per cent. in 1915-1916. There has only been a partial recovery in the interval, but the high prices realized by the growers in the season 1918-19, and the resumption of the export of raw fibre, will both tend towards increased cultivation in the next season.

Whether or not the present jute-growing area is capable of producing all the fibre which will be required is the subject, just now, of considerable discussion: for it is realized that very high prices are only an encouragement towards the production either of substitutes, artificial or otherwise, or towards the cultivation of jute in other countries. Either of these would mean the breaking of the conditional monopoly in the production of jute which India has hitherto held.

There is no doubt that the area producing jute and similar fibres in India could be largely expanded, and it is a matter of considerable urgency that a definite policy should be taken up, so that we may be prepared for emergencies if they arrive. It is satisfactory to be able to note that some steps have already been taken, since the profitable nature of fibre production, as compared with other crops, cannot be denied.

Only about 85 years ago, *i.e.*, about 1830, the *"Dundee flax and hemp spinners used to guarantee their products free from Indian jute. Then in 1838 the value of jute yarn was discovered and the Dundee jute industry was born. Seventeen years later, in 1855, the first spinning machinery was brought out to Calcutta from Dundee .. ..Eight tons a day was the product in the beginning." It is now 3,000 tons a day, more than five times as much as the consumption of Dundee, and nearly two-thirds of the total production of jute. The following table † shows how the increase in the number of jute mills in Bengal has proceeded :—

TABLE 2.—*Increase in the number of jute mills in Bengal since 1855.*

Year	Number of mills.	Number of looms.
1855	1	...
1870	5	1,250
1880	18	3,500
1891	24	8,814
1901	34	15,336
1910	45	32,044
1917	71	40,030

Prior to the commencement of the war, the Calcutta mills had practically confined themselves to the manufacture of gunnies and hessian cloth ; but with the advent of the war, they were first of all called upon to manufacture large numbers of sand bags for the

* *Vide* "The Romance of Jute," D. R. Wallace, Calcutta, 1909.
† (Figures supplied by the Director of Statistics.)

trenches This was the more necessary, because the export of the manufactured jute goods from India direct to the various theatres of war, not only saved freight in carrying raw materials over the longer journey to and from Dundee, but also eliminated the exposure of vessels in the most dangerous submarine zone round the British Isles.

The overrunning of Russia by Germany in 1915-16 cut off, to a very large extent, the supply of flax to the allies, and shortage of this fibre, for the manufacture of the huge quantities of tent cloth, tarpaulins, waggon covers, ground sheets, water buckets, etc., required, soon began to be felt. The canvas difficulty was most serious, and as no other substitute was available in sufficient quantity, recourse was had to jute. Small quantities of jute canvas had been manufactured in Calcutta for some years before the war, by the Ganges, Gouripur and Angus Mills; but in February 1918, the Controller of Jute Manufactures arranged with all the mills to make it and, in the interval, about 5,000,000 yards have been made. Jute canvas is practically, therefore, a war development.

Jute canvas.

Jute is not a high class fibre, like flax, and jute canvas is not so durable as flax canvas. Its comparative inferiority has indeed been the cause of adverse comment, particularly in cases where the material has had to remain in contact with earth, or exposed to continued damp. The fact remains, however, that the jute canvas has provided a substitute for flax canvas and has restored a position which would have been almost intolerable without it. There seems no doubt that jute canvas has come to stay and that, for certain purposes, there will be a ready market for it in future years.

The situation, in regard to jute during the war, has been an extraordinary one. In 1913-14, the export of raw jute to other countries, including the Continent and Dundee, was about 45 lakhs of bales or half the total crop, and of this quantity Germany and Austria took by far the larger proportion. On the outbreak of war, with a very large crop in hand, the whole of the export to the enemy countries, and later on to Italy, was cut off; while shipments even to England were necessarily severely restricted. At the same time as already described, there arose a great demand for jute manufactures in the shape of sand bags, canvas, corn sacks, etc., for war purposes, for which the Calcutta mills had become practically the

Effect of war on the trade.

only important manufacturing agency Thus, there was a plethora of raw fibre, and the price of the latter fell to a low level At the other end, numerous buyers were competing with each other for the manufactured product, the price of which naturally rose considerably. The appointment of Colonel Wilson as Controller of Jute Manufactures brought with it the organized purchase of manufactured goods, eliminated competition amongst buyers and resulted in very large savings to Government and to all purchasers In the case of sand bags, the savings may be gauged from the fact that the control contract and pre-control prices were Rs. 41-0-3 and Rs 73-8-0 per hundred respectively. The corresponding prices for canvas were Rs. 1-1-0 and Rs. 1-11-0 per yard The total savings to the Home and Indian Governments are estimated by Colonel Wilson at approximately two crores of rupees, say £1,300,000 sterling, in the year 1918 alone

II.—Flax.

Numerous experiments have shown that there are possibilities in India for the production of flax on a considerable scale. In the United Provinces, the investigation had justified the distribution of seed to cultivators for the production of straw; but this had to be abandoned for the time being, because no suitable agency was forthcoming for the extraction of the fibre. There is a similar opening in North Bengal for the production of flax straw as a cultivator's crop, if the extraction of the fibre can be arranged for independently. Careful experiments in both Bihar and in Assam indicate that the crop could be cultivated with profit in those tracts even at pre-war prices for the fibre.

The position in regard to flax on the outbreak of war has already been described, and an appeal was made to India by the Home Government to encourage the production of flax as far as possible. To introduce a practically new crop sufficiently quickly, and on a sufficiently large scale, to affect the supply of flax seriously, was impossible; but interest has again been renewed and the high prices at which flax is selling, and is likely to continue to sell, will help to sustain it until such time as flax is a more or less normal item in the crop rotations of the more suitable tracts. It should be mentioned that at least one large firm is contemplating the purchase of flax straw from cultivators.

III.—Sann hemp.

At the time when the shortage in flax was being severely felt, one of the writers of this article advocated the use of suitably prepared sann hemp (*crotolaria juncea*) as a worthy substitute for flax in canvas.

In contrast to jute, sann hemp has the advantage of being a fibre of the same class as flax, and articles made from sann hemp would, therefore, while probably not so good as those made from flax, be of a markedly more durable nature than jute goods. The necessary samples were prepared and the opinions expressed, while by no means universally favourable, leave no doubt that softened sann hemp is capable of being made into a decidedly better class of canvas than jute.

Commercial prospects.

Moreover, two large commercial concerns have taken up the matter and one of these has arranged for the importation of flax spinning machinery, which is to be used for the working of sann hemp and, in part, for flax when it becomes available. It is necessary to state that the uses of sann hemp will extend to all the coarser materials which have hitherto been made from flax, such as hose pipes, belting, canvas and, possibly, shoe-maker's thread. There seems little doubt regarding any of these, excepting the thread, for the making of which flax has a considerable advantage in its longer ultimate filaments (flax : sann=25 : 10). Encouraging results have, however, been obtained. Thus a new industry is likely to be brought to the banks of the Hooghly as a direct result of the war.

Sann hemp is a widely spread Indian crop and the plant (*crotolaria juncea*) is a papilionaceous legume, which as is well known collects atmospheric nitrogen, through the agency of bacteria, which attach themselves to its roots. The Indian cultivator recognizes sann hemp as a crop which enriches his land and any extended use for the fibre, as outlined above, would involve a corresponding addition to the agricultural resources of the country. Indeed, under certain circumstances, the crop may realize the ideal, long aimed at by agriculturists, of combining a green manure with a revenue crop. So far indigo is the only crop which has approached such an ideal, but the possibilities of sann hemp in this direction have already been recognized by the Government of India.

Saltpetre Manufacture in India.

By J. C. Fergusson, I.C.S.,
Commissioner of Northern India Salt Revenue.

With the exception of small quantities made in Madras for local consumption and in a few Native States in the north, the production of saltpetre in India is practically confined to Bihar, the United Provinces and the Punjab, in which provinces it is under the control and supervision of the Northern India Salt Revenue Department The recognised centre of the industry is Farrukhabad in the United Provinces, but the refined saltpetre of the Punjab is superior to that of either the United Provinces or Bihar. Preparation is by solution, concentration and subsequent refinement from earth containing nitrates, the product of bacterial action in the soil in and around villages, where a large quantity of nitrogen is derived from the excreta of men and animals and the decay of vegetable matter. Nitrous sites are worked on leases given by the landowners, whose growing demands in certain tracts have recently been proving a hindrance to the expansion of the industry. The refiner in the Punjab is, as a rule, a man of capital who takes out the licenses for the manufacture of crude saltpetre in his own name, employs his own servants on the work and defrays all contingent expenses. The same custom is followed by the Muttra refiners in the United Provinces. Elsewhere in Northern India, the *lunya* (the small manufacturer of the crude product in the villages) himself takes out the license to manufacture for which he has to pay a fee of one rupee only, pays the lease-money for the nitrous site and sells his output to the refiner through a middleman, by whom he is financed from start to finish.

In the manufacture of crude saltpetre, nitrous earth scraped during the dry season from the roads, walls, etc., of the site leased for the purpose, and mixed with an equal weight of residual earth of the previous season's working, is carefully packed on a false

bottom of bamboo and matting in shallow filter-beds of clay with an orifice at the bottom Water is poured over the earth and the liquor which runs through containing salt and other substances, as well as saltpetre, is allowed to settle and is then boiled in iron boilers (United Provinces and Bihar) or evaporated by solar heat in cement pans (Punjab). When the liquor has sufficiently concentrated, it is left to cool and the crude saltpetre, which still contains a large percentage of common salt, crystallizes out Under the terms of his license, the *luniya* is not allowed to carry the process further or to educe any salt. The crude saltpetre of the United Provinces and Bihar yields as a rule from 40 to 50 per cent. of refined saltpetre : in the Punjab, the average yield is about 30 per cent.

Process of manufacture of crude saltpetre.

In the refineries, the license fee for which is Rs. 50, refined saltpetre is produced in two ways. In the one, crude saltpetre is dissolved in the mother liquor from the crystallising vats, which is already saturated with sodium chloride. By heating to the boiling point, the potassium nitrate is dissolved and during subsequent concentration the sodium chloride is deposited as crystals and taken out. There then remains a saturated solution of both potassium nitrate and sodium chloride which, on cooling very slowly in evaporating vats, yields crystals of fairly pure potassium nitrate. The other process consists of the treatment of the earth round the refinery, which is saturated with the waste saltpetre resulting from the working of the factory. The saltpetre is recovered much on the same principles as those adopted by the *luniya*, but with rather better plant and greater care, and the process is continued to the eduction of salt. The resultant product, known as *kuthia* saltpetre, is of high refraction, mainly from 20 to 40 per cent. The refiner has the option, under his license of paying duty on his educed salt and passing it into consumption or of having it destroyed.

Refining.

The methods of extraction and refinement have been very fully described in detail by Dr. Leather (Imperial Agricultural Chemist and by Mr. Hutchinson (Imperial Agricultural Bacteriologist) in Bulletins nos. 24 and 68 respectively of the Agricultural Research Institute, Pusa, and are also summarised in Appendix F of the Indian Industrial Commission's Report, in which publications will be found valuable discussions of the possibilities of increasing the

sources of supply and improving the methods of production, as well as of the practicability of relaxing the hampering restrictions imposed on the industry in the interest of the salt revenue In this brief note it is impossible to recapitulate these discussions, which merit the careful attention of all those interested in the industry. The outcome of them, to quote the last mentioned report, is that "the position justifies experimental working on a large scale with expert assistance and control. There is sufficient work for a bacteriologist, a chemist and a chemical engineer in the initial stages; and the result may very likely be a great increase in the output, with a saving of waste and a cheapening of production.' The Industrial Commission recommend that "the work should at first be taken up by the Imperial Department of Industries, which they propose, or by a single local government, and the results so obtained demonstrated by provincial departments of industries." They also make suggestions for the transfer of the control of the industry to local governments.

As regards the quality of the saltpetre produced under existing conditions, as things now stand the refiner's best product in the Punjab is only of about 4 per cent. refraction, while in Bihar it is seldom better than 8 per cent., unless reduced by washing, a process which in practice does not pay, owing to the loss of weight. The Bihar refineries find their best profit in their *kuthia* output, which is cheaply produced and for which—mainly of 25 to 30 per cent. refraction—there is a considerable demand for manurial purposes and the manufacture of fertilizers.

History of the industry.

Up to 1860 or a little later, India was almost the only source of saltpetre, but the discovery of a method of making saltpetre artificially from the nitrate deposits of South America and the German potash beds hit the Indian trade very hard, and whereas the exports in 1858-59 were over 35,000 tons they had dropped in 1913-14 to 13,400 tons. In the five years immediately preceding the outbreak of war, India's principal customers, taking amongst them nearly the whole of the exports, were the United Kingdom and the United States, (both demands steadily declining) China, Ceylon (demand steadily increasing) and Mauritius, the first two taking low refractions, China up to 15 per cent. for fireworks and Ceylon and Mauritius high refractions for manures. Small quantities also went elsewhere, *e.g.*, for curing and other purposes.

In recent years, the detailed figures of the exports in tons were as follows :—

TABLE 1.—*Showing the exports of saltpetre from* 1909 *to* 1918 *in tons*

Country.	1909-10.	1910-11	*1911-14.	1914-15.	1915-16	1916-17.	1917-18.
United Kingdom .	3,807	3,050	2,325	9,112	16,680	23,010	20,[illegible]06
United States of America . .	5,421	4,440	2,381	708	490	650	713
China . .	4,114	4,275	4,225	1,043	883	..	.
Ceylon . . .	980	1,142	1,070	2,100	1,622	53	..
Mauritius . .	2,031	2,530	1,858	1,360	225	320	295
All other countries .	1,558	935	1,170	726	793	2,208	1,278
TOTAL .	17,911	16,381	13,080	16,398	20,702	26,370	22,782

After 1914 the output was diverted to the United Kingdom for munitions purposes, the export of high refractions being stopped, and steps were taken to increase the output, already stimulated by a rise in price, by the reduction to Re. 1 of the license fee for crude manufacture, the issue of licenses through post-offices, permission to compound for the duty on salt educed in refineries, and the opening of areas hitherto prohibited on account of the relatively high proportion of salt contained in the earth. The results of these measures will be seen in the following figures :—

Effect of the war.

TABLE 2.—*Number of licenses issued for production of crude saltpetre.*

Year	Bihar.	United Provinces.	Punjab.
1913-14	24,515	5,273	1,371
1914-15	20,070	6,270	1,648
1915-16	30,501	8,495	2,291
1916-17	30,251	11,100	3,467
1917-18	37,388	11,054	2,089

*Includes average figures for the years 1911-12, 1912-13 and 1913 14. The exports during these years to all countries were practically stationary.

TABLE 3.—*Number of refineries licensed.*

Year.	Bihar.	United Provinces	Punjab.
1913-14	213	82	32
1914-15	205	83	33
1915-16	213	95	37
1916-17	227	138	48
1917-18	248	146	50

TABLE 4.—*Production of refined saltpetre in maunds.*

Year.	Bihar	United Provinces.	Punjab.
	Mds.	Mds.	Mds.
1913-14	1,85,373	1,60,756	87,010
1914-15	2,22,123	1,88,380	1,06,176
1915-16	2,19,505	2,36,058	1,52,301
1916-17	2,41,038	3,00,550	2,45,970
1917-18	2,30,431	2,58,838	1,50,058

Exports similarly rose to over 26,000 tons in 1916-17 and over 22,000 tons in 1917-18. The fall in production during 1917-18 was due to abnormal rainfall during the manufacturing season.

The following table gives the prices prevailing at Calcutta per factory maund of 74·67 lbs. of 5 per cent. refraction saltpetre during January and July of each year from 1897 to 1916 :—

TABLE 5.—*Calcutta price for factory maund of 5 per cent refraction saltpetre since* 1897

Year	January.			July.		
	Rs.	A.	P.	Rs	A.	P.
1897	6	1	0	6	4	0
1898	5	15	0	5	12	0
1899	6	5	0	6	7	0
1900	6	12	0	6	8	0
1901	6	5	0	6	12	0
1902	6	11	0	7	0	0
1903	6	9	0	6	14	0
1904	7	0	0	7	4	0
1905	8	8	0	9	0	0
1906	8	6	0	8	8	0
1907	8	4	0	9	8	0
1908	8	10	0	8	8	0
1909	8	2	0	8	6	0
1910	8	8	0	9	0	0
1911	10	8	0	11	8	0
1912	11	4	0	11	8	0
1913	11	12	0	11	8	0
1914	12	3	0	11	4	0
1915	11	12	0	11	4	0
1916	13	4	0	15	8	0

In 1916, owing largely to market manipulation rather than to any increased price obtained by the manufacturers, selling rates rose so high that they had to be artificially restricted, and the export of saltpetre was prohibited, if shipped at prices working out higher than Rs. 13-12 a factory maund for 5 per cent. (or less)

and Rs. 12-14 for 10 per cent. refraction f. o. r. at port. These rates, which gave no incentive to efforts to produce lower refractions than 5 per cent. were under re-examination when the munitions demand ceased, refiners complaining that the great rise in the rents of nitrous sites, wages, the cost of sheet iron for boilers, and of fuel, etc., had deprived them of any profit in the business.

Future prospects.

The future of the industry is somewhat obscure, and depends on the demand for saltpetre "whether," to quote the Industrial Commission once more, in their remarks on the degree to which the restrictions on manufacture imposed in the interest of the salt revenue might justifiably be relaxed, "as a source of explosives or other manufactures, or for its manurial value in India and countries comparatively near India—a factor which is likely to be affected by the degree of importance that may be attached to the maintenance of a British Empire source of supply. It is likely that the demand for these purposes will assume considerable importance. Gunpowder will always be wanted in large quantities, while the preservation of foods and the manufacture of glass also require saltpetre. The lines of action that should be pursued should be in the first place to systematise, improve and cheapen the processes of manufacture. This will give a suitable basis for the next step—the increase of the sources of production."

The Indian Pine Resin Industry.

By A. J. Gibson, I.F.S., F.C.H., F.L.S.,
Deputy Conservator of Forests, Resin Forest Division, Punjab.

The production of rosin and turpentine by distillation from the resin of the low-level Himalayan pine, *pinus longifolia*, has made rapid strides in India in the last few years, and the forest department factories at Bhowali, United Provinces, and Jallo, Punjab, have been hard put to it to meet all the demands on them, as imports of rosin and turpentine (mainly American, either direct or *viâ* the United Kingdom), have been reduced very greatly since the war began. Modern methods, too, have succeeded in standardizing Indian rosin and turpentine as manufactured at the Jallo Factory, and the United Provinces are copying both the plant and the system in their new factory now under construction at Bareilly. The industry, consequently, shows considerable promise for the future.

The Ordnance Department have made use of the rosin for shrapnel shell filling and varnish making to a considerable extent, in the last two or three years, while without the Indian turpentine, railways, and other large paint-consuming concerns would have had great difficulty in getting their essential paint-work done. Rosin is an important constituent in paper and soap making, while rosin-oil, the product of the destructive distillation of rosin, is the main ingredient of a class of largely used lubricating greases. There is thus every reason to continue developing the industry along sound commercial lines to meet the demand in India for articles so far largely imported.

For the year ending 30th June 1918, the United Provinces and Punjab Forest Departments were working 2,485,222 blazes in their forests for crude resin, over an area of 92,493 acres, the production of turpentine being 141,407 gallons and of rosin 58,500 maunds (1 maund = 82$\frac{2}{7}$ lbs.). The subjoined table contrasts the figures

of 1917-18 with imports *plus* Indian output in the past ten years :—

TABLE 1.—*Imports and production of rosin in India during the past ten years.*

Financial year.	Rosin (maunds)			Turpentine (gallons).		
	Imported.	Indian output.	Total.	Imported.	Indian output.	Total.
1907-08 . .	104,160	6,600	110,769	222,560	16,086	238,646
1908-09 . .	79,520	9,811	89,331	253,570	23,592	277,162
1909-10 . .	87,640	10,449	98,089	194,760	24,105	218,865
1910-11 . .	56,840	9,054	65,894	197,720	17,051	214,771
1911-12 . .	93,472	12,268	105,740	266,443	27,756	294,199
1912-13 . .	85,424	27,903	113,387	251,079	60,249	311,328
1913-14 . .	62,703	27,429	90,132	193,937	58,803	252,740
1914-15 . .	34,052	33,862	67,914	142,438	78,489	220,927
1915-16 . .	43,071	47,149	90,220	86,700	111,835	198,535
1916-17 . .	25,701	59,523	85,224	80,000	125,663	205,663
1917-18 . .	44,094	60,938	105,032	140,772	136,052	276,824

These figures show that the local manufacture is having a steady effect on imports but that a considerable amount of expansion is still necessary to secure the Indian market fully.

There is enormous scope for such expansion; thus, the area of Government owned *pinus longifolia* forests which could be tapped can be estimated at close on 420,000 acres, while forests in Indian States would double this figure. In addition, large areas of other species of pine in the Himalayas of the Punjab, United Provinces, Assam and the hills of Burma will become available as soon as communications are improved or developed. One may put the ultimate maximum annual production of Indian rosin and turpentine at

600,000 maunds and 1,600,000 gallons respectively. With such an output at its command, India could probably meet the demands of Africa, the Straits, China, Java and Australasia as well as her own, but it will require many years of effort and organised expansion before such yields can be thought of, far less be attained

Enquirers should address the Manager, Bhowali Factory, Bhowali Post Office, Naini Tal District, United Provinces, or the Deputy Conservator of Forests, Resin Forest Division, Lahore, Punjab, and these officials and the undermentioned agents will always be glad to give information, quote rates and furnish samples:—

Calcutta.—Messrs. Crawford & Co., Ltd, 8, Clive Street.

Bombay.—Messrs. Wilkinson, Heywood & Clark, Ltd, Oriental Buildings

Madras.—The Bombay Company, Limited.

Karachi.—Messrs. John Fleming and Co.

Indian rosin as manufactured at Jallo has been pronounced superior in many respects to American, while Jallo Quality I turpentine has been certified as very suitable for paint manufacture by the Railway Board Test House, Alipore. Further information on the subject of Indian rosin and turpentine is available in the following publications, as well as in the Annual Forest Reports of the United Provinces and Punjab Forest Departments, articles in the "Indian Forester" and ledger files of the Forest Economist branch of the Imperial Research Institute, Dehra Dun.—

1. "The work of the Forest Department in India" edited by R S. Troup, I.F.S., pages 42-48. (Superintendent of Government Printing, India, 1917). *Price annas four.*
2. "The resin industry in Kumaon" by E. A. Smythies, I.F.S. (Superintendent of Government Printing, India, 1914). Forest Bulletin No. 26. *Price rupee one and annas four.*
3. "Report on Modern Resin Factories as applied to India," by A. J. Gibson, I.F.S. (Superintendent, Government Printing Punjab, 1914).
4. "Notes on Turpentines of Pinus Khasya, Pinus Merkusii and Pinus excelsa," by Puran Singh, F.C.S. (Superintendent of Government Printing, India, 1913). Forest Bulletin No. 24. *Price annas two.*

Magnesite.

By Dr. H. E. Watson and Dr. J. J. Sudborough.
Indian Institute of Science, Bangalore.

Very extensive deposits of some of the finest magnesite in the world are found at Salem in the Madras Presidency, but although this mineral is usually considered to be of considerable value, the Indian deposits do not appear to be worked to an extent at all comparable with their size. This is due to a variety of causes, the chief of which appears to be the small demand both in the country itself and for export purposes. The only other magnesite of purity comparable with that of the Madras product is of Grecian, German or Austrian origin and it is possible that the export trade from India may develop to a considerable extent, as the world's demand is large. For instance, the United States imported in 1903 50,000 tons of the crude and calcined material.

Cement.

In addition to the export trade, there seems to be no reason why the magnesite should not be used more largely in this country for the manufacture of cement. The process is a simple one. The magnesite is first calcined at a dull red heat in an ordinary lime kiln, or, if it is desired to collect the carbon dioxide, in iron retorts. The residue of magnesium oxide (magnesia) is then ground and is ready for use. To make the cement, this magnesium oxide is moistened with a concentrated solution of magnesium chloride. The solution should contain a quantity of chloride between 15—25 per cent. of the weight of oxide.

Such a cement sets very rapidly, but would be too hard and too expensive for ordinary use. In practice, it is always mixed with some inert material such as sand, asbestos, sawdust or emery, and it is then found to possess remarkable binding powers. Five parts of magnesia with 95 parts of sand will give a medium quality artificial stone. If the proportion of magnesia is raised to 15 per cent., the

stone produced is stronger than nearly all the natural stones which are used for building purposes. By suitably mixing the ingredients and introducing colouring materials, an imitation marble may be produced, which will take as high a polish as the best natural stone.

If emery or carborundum is mixed with about 15 per cent. of the cement, and the product moulded, emery wheels of fair quality, and containing only a small percentage of binding material are obtained

When sawdust is used as the filling material, the resulting product is springy, and makes an admirable flooring, which can be laid down without joints and fitted into any shape desired. It is usual to cover this springy layer with another one containing a mineral filling. This upper layer can be made of any colour and finally polished.

These floorings, in spite of many advantages, do not appear to have been used in India, because it has been found in some cases that they tend to warp, and it is said that they cannot be laid on an ordinary lime concrete bed. Experiments which have been in progress at the Indian Institute of Science for some time, seem to show that the warping is mainly due to the use of too much magnesium chloride, and to imperfect mixing, while there is no objection to lime concrete as a bed. Larger scale experiments will be necessary before this can be proved conclusively, but it is possible that the use of magnesia for this purpose may be considerably developed.

Another objection to the use of magnesia cements has been the difficulty of obtaining magnesium chloride. Owing to the high price of hydrochloric acid in India, it is almost out of the question to manufacture the chloride from magnesite, but it has been found that bittern water makes a very effective substitute for all except perhaps the highest grade cements. An enormous quantity of this bittern water is thrown away at all common salt factories, and is to be had at a nominal price.

Tiles can also be made in a similar manner. High-grade tiles usually have a foundation made from sawdust and the cement, and this foundation is covered with a thinner layer having a fine earthy material as the filler. This layer may be coloured or mottled in various ways and is usually given a high polish. Some low-grade tiles have been made in the Madras Presidency by using a mineral filler and bitterns in place of magnesium chloride. When bitterns are used, there is sometimes a tendency for a white efflorescence

to make its appearance on the surface of the tiles or flooring, but this is not marked if the proportion of bitterns used is not too high.

Magnesite bricks.

In addition to its use for cement, magnesite is a valuable material for making bricks for furnace linings The ordinary calcined magnesia cannot be employed for this purpose, as it absorbs moisture and carbon dioxide from the atmosphere If, however, the temperature of calcination is very greatly raised, considerable shrinkage takes place, and the product, which is known as "dead burnt" magnesia, no longer absorbs moisture and carbon dioxide. If it is then moulded into bricks, using about 20 per cent of lightly burnt magnesia and some water as binding material, and refired, a very high class refractory brick is obtained. Unfortunately, the temperatures required for dead burning are so high that they can only be obtained with high-grade fuel and special kilns, and it has hitherto not been found possible to make these bricks at a profit near the source of the mineral.

All the magnesite bricks required by the Tata Iron and Steel Works are now manufactured in India by the Kumardhubi Fireclay and Silica Works and they are stated to be quite equal in quality to imported bricks.

Magnesium sulphate.

Finally, there is a possible use of magnesite which has been frequently considered in this country, namely the production of magnesium sulphate, or epsom salts, by treating the magnesite with sulphuric acid. Although magnesite is so cheap, the price of sulphuric acid is very high, and in normal times the cost of the acid is nearly as great as that of the imported finished material. It is just possible that a large factory might run with a narrow margin of profit, if a good price could be realised for the carbon dioxide, but the total demand in the country does not appear to be sufficient to warrant the establishment of such a concern. During the war, magnesium sulphate has been manufactured at a profit by several firms in India: one company has been making about 300 tons a month from their own sulphuric acid. Whether the manufacture will be a paying industry after the war seems to depend on (*a*) whether the cost of production of sulphuric acid in India can be appreciably reduced (see p. 61) and (*b*) possible competition by the production of magnesium sulphate from Indian bitterns (see p. 307).

Mica and Micanite.

By G. H. Tipper.
Geological Survey of India.

I.—Mica

With the exception of a small quantity of phlogopite won in Travancore the mica mined in India belongs to the variety known as muscovite.

The chief mining centres are (1) the Bihar mica belt, a strip of country about 12 miles broad and 60—70 miles long, running obliquely across the Monghyr, Hazaribagh and Gaya districts in the province of Bihar and Orissa, (2) the Nellore district in the Madras Presidency. An attempt is now being made to open up a promising area in Ajmer-Merwara, Rajputana.

Nature and localisation.

The rocks in which mica occurs in paying quantities are known as pegmatites and may be looked on as the end product of a granitic magma, the constituent minerals being mica, felspar (commonly microcline), and quartz. Crystallisation took place at a comparatively low temperature under conditions of absolute quiescence, resulting in the segregation of the constituent minerals into large and comparatively pure masses. The forms of the so-called pegmatite "intrusions" vary greatly. The more regular and restricted sheets and dykes with a regular strike and dip are those which are more easily mined. Coarseness of grain is not correlated with size of the "intrusion." Large masses are much finer in grain than the smaller and more restricted "intrusions." Almost without exception, those pegmatites carrying payable mica show a well developed central core of quartz, which shades off gradually into softer pegmatite on both walls. Mica is usually better developed on one wall which may be either the hanging or the foot wall.

Certain accessory minerals such as tourmaline, garnet, apatite and beryl are common. Others are rare and include some containing rare earths, samarskite, pitchblende and monazite.

The rocks traversed by the pegmatite "intrusions" are mostly various types of schists. In general, the strike of the "intrusion" is in the same direction as that of the rocks traversed. Exceptions are by no means rare.

Mining methods.

Mining practice differs in the two principal areas. In Nellore, it has been the custom to attack the pegmatites by means of large open quarries. The depth to which such can be worked successfully is limited by the stability of the walls of the quarry, the accumulation of large heaps of waste in the immediate vicinity of the workings and by the depth of water level. In the Bihar mica belt, the majority of the workings are still carried on in the primitive style of sinking a narrow, winding hole from "book" to "book" of mica, while the mica waste rock and accumulated water are raised to the surface by hand. The important factors of dip and strike are not recognised. Although this represents the practice of the majority of workers, some firms are now working in an up-to-date manner with mechanical equipment to deal with waste rock and water. In one or two cases, compressed air drills have been successfully introduced.

The defects from which mica may suffer are many. There are cracks of various kinds, ridging, cross-graining which causes the films to break and not split evenly, inclusions like tourmaline and feathery skeleton crystals of magnetite, air spots due to minute spherical bubbles of air between the finest films, black spots, stains of mud and iron, buckling and waviness of the films.

Good mica should be uniform in colour, free from all cracks, inclusions and flaws. It should split uniformly and easily. It should be flat, giving a perfect reflection. The colour of mica is variable. The Bihar mica belt is the home of "ruby" mica, while in Madras the predominant colour is green.

Trimming and grading.

After the mica has been raised to the surface, it has to be prepared for the market. The green Madras mica is trimmed by means of shears into rectangular blocks which receive no further treatment. The Bihar mica is all cut by the country sickle, with which the trimmer is enabled to cut round all cracks and flaws. The resulting block is very irregular and shows all sorts of re-entrant angles. The advantages of sickle trimming are (1) there is less waste, (2) there are no square corners to fray out, (3) the trimmed

blocks are more easily split, (4) it is not considered as manufactured mica for import into the United States of America

When the mica has been cut, it requires to be graded into qualities, clear, slightly stained, fair stained, black spotted, etc. Mica is sized according to the greatest number of square inches which can be measured as a rectangular figure, leaving out of account irregularities due to cutting and any flaws remaining. The total waste during mining and preparation for the market is very great and, in most cases, is not less than 90 per cent. This is largely due to the fact that it is the condition of the product mined, which is of prime importance, whereas in most other forms of mining the condition of the product is a secondary consideration.

Practically the whole output of mica is exported from India in the form of block mica and splittings. No attempt is made to work up the raw material. Up to the present, the enormous accumulations of waste mica in the different mining centres have not been put to any practical use.

Mica is chiefly used as an insulator in the different forms of electrical machinery. The out-put for the year 1917 was—

	Cwts.
from Bihar and Orissa	34,137
„ Madras (Nellore)	6,059
„ Rajputana	720

II.—Micanite.

Micanite can be best described as reconstructed mica. For this purpose small sized block mica (No. 6 chiefly) is split into the thinnest possible films. The splitting is done by women and children, who use a long, sharp pointed knife. The speed with which the splitting is done is remarkable. The films so obtained are cemented together with shellac dissolved in spirit. The films are spread by hand on a sheet of brown paper and are then sprinkled with the cementing material, which is brushed over as uniformly as possible. On this is laid another layer of films and then more shellac, until a sheet of the required size and thickness has been built up. These sheets still require to be steamed, pressed, rolled and trimmed. Not only is it possible to make sheets of any size, but, with suitable moulds, odd shaped insulators can be prepared.

In spite of the fact that the raw materials are all to be obtained in India (of shellac it has a monopoly) and a plentiful supply of cheap labour, micanite is only being manufactured in small quantities.

Hardware.

By H. A. F. Musgrave,
Superintendent of the Government Test House, Alipore.

Definition.

Hardware, speaking generally, is what is known in the trade as "Shelf Goods", the items of which are contained in the Sheffield and Birmingham Chambers' list completed and published more than a century ago. The term includes electroplated ware and cutlery, agricultural implements, domestic utensils, iron and galvanized iron buckets, lamps of all kinds, machine tools (*i.e.*, tools for use in metal cutting machinery) and hand tools for all trades, small machinery worked by hand, brass ware, such as gas, water and electric fittings, fire hydrants, cocks and taps, safes and strong boxes and many other articles too numerous to mention here. Outside the trade, the term "iron-mongery" is in more general use and it is those classes of hardware, which the ordinary person calls iron-mongery to which this article is principally confined.

Difficulties caused by the war.

Before the war, the bulk of India's requirements was imported, and in the years 1912-13 and 1913-14 the total value of all kinds of hardware brought into the country averaged nearly two and a half million sterling. On its outbreak our needs were greatly increased, because, owing to their work and conditions of life, troops in the field require large quantities of hardware, which they would not otherwise use. This is specially true of Indian troops, who in civilian life use very little imported hardware, but as soldiers have to be supplied with all kinds of utensils to army pattern. But so far from increased supplies being available, it was soon found necessary by the Home Government to prohibit export of hardware almost entirely, licenses only being issued for the export of such articles as were considered necessary, either directly or indirectly, for carrying on the war. A certain amount of material

was fortunately held in stock by merchants in India, but as the time went on their stocks became depleted and the question of meeting indents became increasingly difficult. The result was that very soon after the commencement of the war great difficulties were experienced in obtaining hardware necessary for the armies in the field.

This state of affairs naturally stimulated the manufacture of certain articles in this country and also led to increased but inadequate imports from Japan and America. These were confined, however, to certain articles, and a large number of things previously imported from Austria and Germany were almost unobtainable. American goods were on the whole satisfactory, but many of the articles that came from Japan were of inferior quality.

Buckets of galvanised and tinned iron.

As the following table shows, during the war imports of galvanised iron and tin buckets, which used to come almost entirely from the United Kingdom, practically ceased

TABLE 1.—*Imports of galvanised iron and tinned buckets from 1913—18.*

Country of origin.	1913-14	1914-15.	1915-16.	1916-17.	1917-18.
	£	£	£	£	£
United Kingdom . .	66,073	44,085	9,730	8,376	5,894
TOTAL (INCLUDING OTHER COUNTRIES).	67,065	45,133	9,789	8,568	6,298

There was no falling off in demand, but the deficit was to some extent made up by factories in India, which were equipped specially for the manufacture of this class of goods from imported sheets.

Builders' hardware.

The following table shows the imports of builders' hardware, such as locks, hinges, door locks, etc.:—

TABLE 2.—*Imports of builders' hardware into India from 1913—18.*

Country of origin.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18
	£	£	£	£	£
United Kingdom . .	63,079	53,390	60,576	63,344	29,383
Germany	69,858	24,780	1,943	175	..
Japan	73	7	936	16,337	36,302
United States of America .	13,985	7,193	25,456	41,528	53,303
TOTAL (INCLUDING OTHER COUNTRIES).	164,176	94,871	115,355	146,360	122,443

Before the war, the import trade was divided almost equally between Great Britain and Germany. Imports from England have dropped over 50 per cent., while those from Germany ceased. Both the American and Japanese fittings, however, have come in in large quantities while local manufacture has greatly developed, so that the shortage has not been so marked as in most other classes of hardware.

TABLE 3.—*Imports of domestic hardware, other than enamelled ware, into India from 1913—18.*

Country of origin.	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.
	£	£	£	£	£
United Kingdom . .	55,750	40,427	31,370	36,464	20,943
Germany	46,910	12,013	891	474	..
Japan	6,390	2,041	6,720	9,789	7,405
United States of America .	3,054	2,981	3,928	5,488	8,827
TOTAL (INCLUDING OTHER COUNTRIES).	124,654	62,301	51,188	58,819	44,078

As in the case of builders' hardware, the United Kingdom an Germany were the principal importers and their trade has falle off in a precisely similar way. But in this case other countries hav not stepped into the breach.

Hardware.

TABLE 4.—*Imports of enamelled ironware into India from 1913—18.*

Country of origin.	1913-14	1914-15.	1915-16.	1916-17.	1917-18.
	£	£	£	£	£
nited Kingdom . .	15,381	10,484	7,807	11,101	14,715
ermany	41,055	13,375	497	538	20
ustria-Hungary . .	124,622	40,323	65	627	2,287
pan	499	1,703	47,763	116,847	100,419
TAL (INCLUDING OTHER COUNTRIES.)	184,451	66,794	57,856	131,926	123,908

Before the war, this trade was, almost entirely in the hands of ermany and Austria At present, Japan is the largest importer, ut two companies in Calcutta have undertaken the manufacture of amelled ironware, and one at least will shortly be placing its oods on the market. With the likelihood of the manufacture of on sheets in India, and the constantly growing demand for articles f this material, these ventures appear to have a good future before iem.

ABLE 5.—*Imports of implements and tools other than agricultural implements and machine tools from 1913—18.*

Country of origin	1913-14	1914-15.	1915-16.	1916-17.	1917-18.
	£	£	£	£	£
nited Kingdom . .	211,030	189,283	148,201	160,213	124,882
ermany	16,088	6,602	1,015	84	..
elgium	5,900	2,480	280	19	..
apan	4	9	107	774	4,156
nited States of America .	31,837	25,158	54,845	45,301	111,151
OTAL (INCLUDING OTHER COUNTRIES).	271,631	225,003	209,914	210,780	245,040

Local manufacture has been hampered by the shortage of tool steel, which is not yet made in India and could only be spared y other countries for essential war purposes.

TABLE 6.—*Imports of metal lamps into India from 1913—18.*

Country of origin.		1913-14	1914-15.	1915-16.	1916-17.	1917-18.
United Kingdom .	No.	504,558	288,742	117,080	78,810	36,806
	£	*44,537*	*32,347*	*19,333*	*20,317*	*10,008*
Germany . . .	No.	1,086,727	460,623	45,470	7,154	184
	£	*67,625*	*25,712*	*2,141*	*163*	*12*
Austria-Hungary .	No.	412,584	143,670	..	210	6
	£	*33,531*	*9,810*	..	*15*	*9*
Japan . . .	No.	915,118	510,191	340,413	277,801	180,251
	£	*5,435*	*4,143*	*9,143*	*14,317*	*10,294*
United States of America.	No.	1,102,830	473,931	1,035,408	1,520,491	908,707
	£	*118,740*	*49,414*	*118,006*	*163,283*	*128,175*
Share of Bengal .	No.	1,778,311	657,633	810,794	1,010,811	884,312
	£	*137,202*	*50,277*	*82,018*	*110,371*	*93,231*
" *Bombay* .	No	1,480,062	732,410	535,711	686,907	371,878
	£	*67,274*	*36,763*	*52,072*	*62,980*	*43,190*
" *Sind* . .	No.	754,747	165,886	80,480	126,581	43,150
	£	*21,524*	*8,602*	*8,309*	*12,488*	*5,603*
" *Madras* .	No.	316,094	218,820	66,350	44,381	27,333
	£	*18,945*	*11,549*	*4,566*	*4,804*	*3,501*
" *Burma*, .	No.	333,224	118,144	63,035	63,388	37,074
	£	*23,587*	*11,927*	*4,754*	*10,658*	*10,011*
GRAND TOTAL .	No.	4,662,438	1,892,890	1,562,070	1,902,138	1,144,327
	£	*273,562*	*126,218*	*151,809*	*201,081*	*165,514*

In 1913-14, Germany and Japan were the largest suppliers of cheap lamps, while United States of America imported most of the better class. The supply of all kinds, however, has naturally been curtailed to a very great extent during the last few years owing to the control of the chief metals used in the manufacture. A good quality of cheap lamp is now being successfully made in India, where lamp glasses are also available. It remains to be seen how these lamps will stand competition, when normal conditions return.

TABLE 7.—*Imports of glass lamps into India from 1913—18.*

Country of origin.		1913-14.	1914-15.	1915-16.	1916-17.	1917-18
ermany . . .	No.	79,260	7,490	240	200	..
	£	*1,025*	*637*	*23*	*10*	..
ustria-Hungary .	No.	181,249	60,108	..	..	..
	£	*3,925*	*912*	..	..	..
apan . .	No	488,004	283,707	478,303	367,844	47,713
	£	*2,802*	*1,691*	*5,129*	*6,811*	*597*
hare of Bengal .	No.	90,808	32,342	86,631	44,014	1,524
	£	*2,001*	*630*	*981*	*1,241*	*24*
„ *Bombay* .	No.	453,340	183,811	225,672	271,800	45,000
	£	*4,391*	*1,378*	*2,568*	*5,517*	*943*
„ *Sind* . .	No.	8,301	5,120	936	21	90
	£	*500*	*236*	*74*	*11*	*9*
„ *Madras* .	No.	102,308	61,055	147,525	47,838	7,305
	£	*3,108*	*927*	*2,004*	*789*	*347*
„ *Burma.* .	No.	22,308	81,006	31,026	21,624	4,100
	£	*915*	*943*	*411*	*620*	*97*
GRAND TOTAL .	No.	773,197	304,080	491,780	386,253	58,169
	£	*11,008*	*4,133*	*6,041*	*8,178*	*1,419*

Nearly two-thirds of the imports went to Bombay and most of he remainder to Madras. Japan had the bulk of the trade and the st came from Germany and Austria. Even Japanese supplies ave dwindled almost to nothing since the war began, although lamps f this kind are believed not to be made in India, where no moulded r pressed glass work is yet produced.

TABLE 8.—*Other sorts of hardware imported into India from 1913—18.*

Country of origin.	1913-14.	1914-15	1915-16.	1916-17.	1917-18.
	£	£	£	£	£
United Kingdom .	910,365	720,154	689,312	818,260	451,832
Germany . . .	217,088	81,896	6,023	2,031	51
Belgium	24,632	8,880	895	..	..
Austria-Hungary . .	27,608	12,478	16	195	593
Japan	14,420	15,337	34,738	134,112	201,888
United States of America .	76,664	57,869	76,518	122,888	175,838
TOTAL (INCLUDING OTHER COUNTRIES).	1,324,744	933,524	868,511	1,151,540	964,858

From the above comments on the imports of hardware into India, it will be seen that Germany and Austria-Hungary have in the past been very extensive suppliers to the Indian market, but that America and Japan are to a large extent taking their places.

Prospects of manufacture in India.

The question of primary interest to the Indian is why India has not been able to seize the opportunity afforded by the temporary stoppage of the imports from enemy countries to secure a permanent hold on the hardware industry. It is true that, owing to the great rise in prices, it became a commercial proposition during the war to make many articles of this class by hand or by methods too expensive for ordinary times, but as a rule, in normal circumstances, it is impossible for the hand-made article to compete against the product of machinery, wherever made. The reason of this is that owing to the steady demand for most of these articles and their simple character, they can be manufactured in large numbers by repetition processes and kept in stock so as to meet all demands. They are, therefore, very suitable to be manufactured by machinery, and as they are durable, and their value is often considerable in proportion to their bulk, they bear the cost of carriage over long distances far better than crockery, glass or furniture. Until therefore the use of machinery becomes far more common in India

than it is at present, it is doubtful whether in spite of the great and increasing demand for all articles of hardware in India local manufacture will be successful. On the other hand, there is no reason to suppose that these difficulties will not be in time surmounted. New companies are being formed for the manufacture of enamelled ware, sheet metal goods, paints, glass of all kinds, galvanized iron goods, etc., and old businesses are being extended. These projects are at present largely in European hands, but once local manufacture becomes established and the prejudice against Indian-made goods disappears there is reason to suppose that, with the supply of trained labour which will be made available by the pioneer firms, other concerns will be started and by degrees a great proportion of India's requirements will be manufactured in the country.

Some Miscellaneous Articles Purchased by the Indian Munitions Board.

By. B. Abdy Collins, I.C.S.,
Controller of Industrial Intelligence.

I.—Brushes.

The manufacture of brushes was an established trade in India even before the war, but it was chiefly confined to the cheaper types of brushes of certain specified kinds and most of the better class brushes, as well as a number of very cheap brushes and brooms, have always been imported from abroad. The following table shows the imports of brushes and brooms into India during the last 5½ years:—

Table 1.—*Imports of brushes and brooms into India from 1913 to 1918.*

Country of origin.		1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1918-19.
		Dozens and value.	Dozens and value.	Dozens and value.	Dozens and value.	Dozens and value.	Dozens and value.
United Kingdom		58,102	[illegible]	[illegible]	52,824	47,154	Total figures for 6 months.
	£	*23,083*	*18,818*	*18,073*	*24,387*	*26,481*	
Straits Settlements		64,417	61,086	61,456	57,805	60,320	
	£	*402*	*450*	*506*	*514*	*641*	
Germany		41,447	21,180	775	81	..	
	£	*5,397*	*2,264*	*141*	*16*	..	
Austria-Hungary		48,300	10,414	..	400	.	
	£	*6,851*	*1,290*	..	*20*	..	
Japan		70,637	52,303	67,718	171,088	102,258	
	£	*3,535*	*2,931*	*5,063*	*10,158*	*24,855*	
Total (including other countries)		313,070	291,738	266,182	303,898	314,721	185,464
	£	*48,495*	*36,461*	*36,050*	*48,786*	*57,865*	*39,599*

The imports from Straits Settlements include a large number of very cheap brooms made of cocoanut leaves, while quantities of cheap brooms made of grass and fibre with thin strips of cane also come from Japan and account for the low average value of her imports. The previous imports from enemy countries consisted very largely of paint and varnish brushes, and most of the good class brushes of all kinds came, and still continue to come, from the United Kingdom, whose trade appears to have been very little affected by the war.

One result of the war has not unnaturally been a great shortage of paint and varnish brushes, of which the better qualities can only be made from French and Chinese bristles, which are at present either unprocurable or only available at almost prohibitive rates. Indian manufacturers have succeeded in turning out suitable sash tool brushes and also horse hair varnish brushes of fair quality, but they are sometimes even now more expensive than imported brushes.

Effect of Government purchases.

During the war, the brush making industry has received a great stimulus from the requirements of Government, especially for the army, and the railways, which seem to have taken most of the output of the existing factories and further to have brought into existence a number of small firms, which work without machinery or merely give out advances to village artisans The types of brushes chiefly purchased have been horse and mule body brushes, brushes for cleaning equipment, such as brass, cloth and miscellaneous polishing brushes, and hair brushes. Of these and other miscellaneous descriptions, Government has purchased during 1918, approximately 300,000 dozens, which is roughly equivalent to the average number imported into India.

Raw materials: wood.

These large orders have undoubtedly brought temporary prosperity to the trade but, with the advent of peace and the renewal of competition from abroad, the future of the industry is by no means free from anxiety. In respect of raw materials, India is on the whole well situated. Before the war, especially for military requirements, imported wood was largely used in order to comply with specifications often compiled in the United Kingdom. During the last three or four years, however, necessity has compelled the acceptance of local woods, many of which have proved to be very suitable for brush

manufacture. It is to be hoped that the specifications for army brushes will now be permanently altered so as to prescribe the use of Indian woods, at least in the alternative The main difficulty so far has been to secure proper supplies of seasoned timber, a difficulty which hampers all users of Indian timber of the lesser known kinds. The problem is one of which the Forest Department are well aware, and it is to be hoped that neither money nor energy will be spared in solving it as soon as possible.

Bristles and fibres.

For bristles and fibres, the Indian manufacturer is also well off The Indian hog bristle is well known in international commerce. It is coarse in texture and does not look so well as the superior grades from China, France, Russia and Austria, but its wearing qualities are said to be much superior. It is, therefore, eminently suitable for use in the army and mills, where looks matter less than lasting. Like most industries, however, in which the lowest castes in India are concerned, the production of bristles is not in a very satisfactory state. The pigs are neglected, with the result that they are attacked by lice which irritate them and cause them to rub themselves whenever possible, and so lead to a high percentage of split bristles. Moreover, in order to get money as soon as possible, the owner of the pig always starts plucking it before the bristles are mature. The result is that the animal suffers considerable pain and the number of short bristles is far greater than would otherwise be the case. The fibres used such as bass, bassine, whisk, *kitul*, etc , are at present largely imported. Much of the *kitul* fibre comes from Ceylon, in spite of the fact that a great deal of it is produced in the south and east of India, whence it is exported in large quantities. The reason of this seems to be that the Indian industry is not yet organised and there is no firm in India which puts the fibres on the market in a form suitable for use by the brush makers. This is an industry which might well receive the attention of the capitalist.

Varnish, glue and other materials.

Before the war the varnish and glue used by brush manufacturers was mainly imported. The glue chiefly favoured came either from the United Kingdom or Italy. Since the war, Indian-made glue has been utilised, but it is very usually inferior and must give way to the imported article when the normal trade conditions return. The prospects of this industry are discussed elsewhere (see page 346) Varnish is at present often made by the brush manufacturers them-

selves from indigenous materials such as shellac and rosin, but unless a good indigenous article is put on the market, it is probable that the manufacturers will again return to imported varnish, as soon as it is available at a reasonable price. The other materials used in brush making such as wire and binding material, screws, etc., are all imported. The wire chiefly favoured is known as "union" wire and is an alloy of copper and zinc, which will probably not be made in India at present. For binding sash tools and paint brushes a temporary substitute has been secured, but it is likely to give way to imported Irish flax again.

Future prospects.

Out of the large numbers of firms who make brushes, only a few use machinery on any scale and can be considered to be organised on the factory system. Most of these concerns are apprehensive of their future when exposed again to foreign competition and are inclined to insist that protection by means of a higher tariff than 7½ per cent *ad valorem* will be necessary. They will undoubtedly also be somewhat embarrassed when the large Government orders are discontinued and they have to build up their civil connection again. The smaller firms are mostly anxious to continue and even to expand their businesses, but require advice and assistance in securing machinery and their raw materials. In view of the many difficult questions involved, it would seem advisable to secure the services of an expert from abroad for a short period to advise Government as to how to proceed to establish the industry on a firm footing.

II.—Cutlery.

The demands of India for cutlery before the war were very large and, as the following statistics show, were chiefly supplied by the United Kingdom and Germany.

TABLE 2.—*Imports of cutlery into India from 1913 to 1918.*

Country of origin	1913-14.	1914-15.	1915-16.	1916-17.	1917-18.	1918-19.
	£	£	£	£	£	£
United Kingdom	77,[illegible]	61,044	52,487	67,417	40,012	Total figures for 5 months only.
Germany	[illegible]	23,[illegible]	1,490	870	.	
Belgium	12,401	4,448	101	.	81	
Japan	[illegible]	[illegible]	8,105	22,[illegible]	21,024	
United States of America	11,[illegible]	6,173	13,606	18,781	27,327	
TOTAL (INCLUDING OTHER COUNTRIES)	[illegible]	[illegible]	72,561	101,879	107,110	63,545

Clasp knives.

Since the war, the imports from Germany have almost ceased, while the place of these two countries, has been to some extent, taken by Japan and the United States of America. The making of knives of various kinds, however, has always been an indigenous industry, especially in the Punjab, where it has been in the hands of the small artisan. The demands of the army have led to a considerable expansion of knife manufacture, chiefly in the direction of clasp knives, large numbers of which were required for the equipment of the individual soldier. After some trouble a wooden handled knife, which could be manufactured by the village artisan, was evolved and, during the seven months ending October 1918, no fewer than 56,000 were purchased, chiefly from centres such as Aligarh, Nizamabad and Wazirabad; while, had not the war come to an end, very much larger quantities would have been purchased in the ensuing year. These knives were manufactured for the most part without machinery, and the work of the artisans was organised by manufacturing firms like Messrs. Johnson & Co., Aligarh, by small capitalists or by blacksmiths of more than average intelligence with capital of their own. Scissors and spoons were also purchased in large numbers in a similar way. The end of the war will mean a great set back to this promising industry, unless arrangements can be made to secure these makers an adequate civil connection. Since many of the clasp knives produced were not only of excellent quality, but compare very favourably in price with the imported article, there seems no reason why these manufacturers should not turn out pen knives and similar articles required by the civil population in large numbers. But it is certain that during the period of change they will require assistance, not only in technical matters, but on the business side of the industry.

The other development in this line has been the manufacture of pruning knives for tea gardens. Even before the war, experiments had been made on a small scale in the manufacture of these knives from waste steel. Since the Indian Munitions Board was constituted, by means of its priority procedure, the opening for the manufacture of these knives was brought to the notice of one or two enterprising firms and they are now being made in Calcutta (see page 22) in numbers practically sufficient to supply the demands of the whole industry. Messrs. Tata & Co. are now providing some of the steel used, for which they undertook to run a special heat. It

is to be hoped that this industry will survive the return of peace conditions.

III.—Buttons.

As might be expected the demands of India for buttons are very large, though a great proportion of those imported into the country must be attached to finished garments and so are not included in the statistics. Separate figures for imports have only been maintained for the last three and a half years, but these show that Japan holds a dominating position in this trade, though Italy also provides a large proportion.

TABLE 3.—*Imports of buttons into India from 1915—1918.*

Country of origin.	1915-16.	1916-17.	1917-18.	1918-19.
	£	£	£	£
United Kingdom . . .	16,740	20,800	10,431	Total figures for 6 months only
France.	3,636	10,141	6,026	
Italy	38,878	55,418	27,795	
Japan	77,371	127,101	80,020	
TOTAL (INCLUDING OTHER COUNTRIES)	138,021	214,093	125,320	61,233

Many of the buttons imported from Japan are of the very cheapest, such as find favour in the Indian bazars, where cheapness as a rule is the primary consideration. The manufacture of buttons in India is to some extent hindered by the prejudice against the collection and the working up of bones, but a number of very high class mother-of-pearl buttons are now made by small firms in India, such as the Tirhoot Moon Button Factory of Mehsi, Champaran District. Curiously enough, however, the products of these firms, which find no favour in India on account of their higher cost, are readily bought in East Africa and Australia, where good quality is appreciated. During the war, the Army Clothing Department has been able to assist this industry by very large orders, as the following purchases

of buttons of various materials made between the 1st of April and the end of October 1918 show :—

	Gross.
Cotton	1,235
Leather	68,896
Zinc	487,362
Horn	64,025
Mother-of-pearl	7,013
Brass	20,572
Bone	25,564

It is to be hoped that these purchases will do much to set the industry on a firm footing, since, like so many other small industries in India, one of its chief difficulties hitherto has been an adequate supply of capital.

A description of the Tata Iron and Steel Works at Sakchi (Jamshedpur).

By T W. Tutwiler,
General Manager.

The works are situated at Sakchi adjoining the Kalimati Station on the Bengal Nagpur Railway. Kalimati is 155 miles west of Calcutta, about 115 miles from the Jherria coal mines and 45 miles from the Company's Gurumaishini iron ore mines

The Tata Iron and Steel Co, Ltd., was formed in 1907 and the original plant was put into operation early in 1912. The plant consists of the following:—

Coke ovens; sulphuric acid plant; blast furnaces; steel works; 40" blooming mill; 28" rolling mill; one 16" and two 10" bar mills; boiler plant; power house; iron foundry; machine shop, blacksmith shop, pattern shop, storage yard; locomotive shed and general main stores, office buildings; etc, etc.

Extensions to the existing plant are being carried out on a large scale and comprise:—

By-product coke ovens; by-product recovery plant and benzol plant; new blast furnaces; steel works; new blooming mill; new rail mill, plate mill; sheet mill, new bar mill, sheet bar and billet mill; wire mill; bolt and nut shop; sleeper press; additional machine shop; foundries and structural shops, new office building, etc., etc

Details of the extensions are given under the respective headings.

Coke ovens. There are 180 Coppée non-recovery coke ovens The Company has also recently installed a battery of 50 Koppers by-product coke ovens which, besides manufacturing coke, give the following by-products —coal tar, sulphate of ammonia, and gas. The Company also has a Simon Carve sulphuric acid plant, which makes sulphuric acid for the purpose of converting the ammoniacal liquor into sulphate of ammonia.

Four batteries of 50 ovens each of the Wilputte type will l required in connection with the extensions to the works. Th will make an additional 200 by-product ovens which will be con plete with a plant for the recovery of coal tar, sulphate of ammoni gas and benzol. In all probability it will be necessary to ere a fifth battery of by-product coke ovens in order to obtain tl necessary coke required for the extensions to the blast furnace plan

Blast furnaces.

The blast furnace plant consists of two blast furnaces equippe with up-to-date charging and weighir apparatus and four Cowper-Kennedy stove The major portion of iron made is sent to the steel works for conve sion into steel and the balance is sold in normal times in this countr and abroad. Before the prohibition of pig iron export from Ind came into force, shipments varying in size used to be made to Burm the Straits Settlements, Ceylon, Java, Manchuria, China, Japa Australia, New Zealand, the United States, River Plate, etc.

A third blast furnace of a somewhat smaller type than tl two foregoing furnaces is practically completed and is expect to be ready for operation early in this year. In addition, thr blast furnaces of a much larger type than those at present workin are in course of construction.

The slag which is formed in the manufacture of pig iron is no made use of in making granulated slag bricks for local use.

Steel works.

The steel works plant consists of one 300-ton furnace, call the mixer, and six stationary open heart furnaces, four of which are of about 50 to capacity per heat and two of 70 tons capacity per heat. Tl liquid pig iron is conveyed from the blast furnaces to the ste works in 30-ton brick-lined ladles and poured into the mixe which receives all the hot metal from the blast furnaces, preparato to its conversion into steel. From the mixer the iron is tapped o into ladles and charged into open hearth furnaces for conversion in steel. When the process of conversion is over, which takes on a average about 8 to 10 hours, the liquid steel is tapped and then ca into "ingots" which are sent on to soaking pits to be read for the blooming mill. (Each heat produces about twenty ingo and each furnace makes on an average 13 heats per week.)

Extensions to the steel works consist of two 25-ton Bessem convertors and one 200-ton tilting furnace, together with a 1,200-to mixer. The method of producing steel in these convertors is know

as a duplex process, which consists of employing the Bessemer convertor in conjunction with the tilting open hearth furnace. The convertors are intended to remove all silicon and as much carbon as is desired from the iron, leaving the tilting furnace the duty of removing the phosphorus and sulphur and bringing the iron to the required percentage of carbon. The elimination of these elements reduces the time necessary to finish a heat in the tilting furnace by about 75 per cent. The larger type of mixer will be necessary in order to take care of the hot metal from the blast furnaces during the week end, when the open hearth furnaces are not working. It is intended to convert the present 300-ton mixer into an additional open hearth furnace after the 1,200-ton mixer has been erected.

It is also proposed to erect a 6-ton electric furnace for the purpose of producing high grade steel. An arc furnace of the Heroult type has been chosen, and current will be supplied at 3,000 volts.

There are at present three soaking pits which are placed in the steel works building. The soaking pits are equipped with mechanically operated lids and an electric overhead charging and drawing crane. The ingots made are 21″×19″ and weigh from 2 to 3 tons each, according to the sections to be made from them. They are taken by a self-tipping electric trolley to the mill tables. A fourth soaking pit of a capacity of 60 per cent. larger than the present soaking pits is in course of construction.

Rolling mills.

The blooming mill consists of a 40″ mill operated by a Galloway engine of 11,000 horse-power. In this mill, the ingot from the soaking pit is made into blooms and billets. In connection with the extensions a new blooming mill, details of which are not yet ready, will be erected in order to roll the increased tonnage of ingots into blooms and billets.

28″ Finishing mills.

The 28″ finishing mill has 3 sets of rolls. The housings are of the open top type and are held down by four bolts. This mill is operated by a 12,000 horse-power 3 cylinder engine and can turn out rails from 100 lbs. to 30 lbs., beams from 15″×6″ down to 5″×3″, angles from 6″×6″ to 3″×3″ and channels from 12″×4″ to 6″×3″.

Blooms from the blooming mill are re-heated in re-heating furnaces before they are rolled. Sections of rails or structural material, after being rolled to required dimensions, are cut by circular saws into required lengths and are mechanically conveyed by rollers to a cooling bed, which is of the moving type. From the

cooling beds, all bars, including rails, are passed through a roller straightening machine in the finishing department, which is equipped with three straightening machines and the usual drilling and planing machines, and an overhead electric crane which runs over the full length of the finishing department

A new rail mill is to be erected having a larger capacity than the existing 28" mill When this rail mill comes into operation, the 28" mill will then be confined to rolling structural material and all rails will be rolled on the new rail mill.

Bar mills.

At first, there was one 16" mill and one 10" mill. In September 1915, one more 10" mill was added so that now there are two 10" mills. The 16" mill makes light rails weighing 30 lbs. to 14 lbs. to the yard, angles of all sizes from 3" to 1¼", and channels from 4" down to 1½", 4"×1¾" beams, and fishplates for rails. The 10" mills are devoted to the production of lighter sizes of flats, squares, rounds, etc.

It is proposed to erect a new bar mill which will be of the latest continuous type and will take billets from the sheet bar and billet mill varying from 1½" to 3" square in lengths of 30.' In this mill the piece being rolled will be in several sets of rolls at the same time and the vertical rolls which will be used in the mill bring about extreme accuracy in the sections.

Plate mill.

A plate mill is now in course of construction and will produce plates from ⅛" to 1¼" thick in various widths up to 84" and various lengths up to 50,' both length and width being dependant upon the thickness. The mill will be driven by a continuous 2,000 horse-power motor taking alternating current at 3,000 volts. After the piece is rolled to the required thickness, it is carried off the back mill table to a table which delivers the plate to a straightening machine and then to a special table of light construction, where the plate will be allowed to cool and be marked to the dimensions, to which it is to be sheared. The mill building is over 1,000 feet long and about 100 feet in width at its widest point.

Sheet bar and billet mill.

This mill will be a continuation of the new blooming mill and will roll billets from 1½" to 5" square for the bar mill and will also roll sheet bars for use in the sheet mill up to 8" wide. It is intended also to roll steel sleeper sections up to 10" wide on this mill. An electrical drive for this mill is being planned.

Sheet mill. The sheet bars will be delivered from the continuous sheet bar and billet mill to the sheet mill, where six special furnaces will re-heat the bars In one end of the furnaces the sheet bars are heated and at the other end the partially rolled product will be re-heated for finishing.

The rolling equipment consists of 2 jump rolls, 2 balanced rolls, 6 finishing mills, and 2 cold rolling mills. All the mills will be driven by a 4,000 horse-power motor taking alternating current at 3,000 volts. This mill will produce sheets to any width up to 38" and of any thickness desired from ⅛" down to 1-100 of an inch. Two large annealing furnaces will be supplied in connection with this mill

Wire mill. It is proposed to construct a plant capable of producing 20 tons of wire of miscellaneous sizes per day of 24 working hours. This will be used for fencing, nails, etc., etc

Bolts and nuts. In the scheme of extensions it is proposed to erect a bolt and nut shop with a sufficient number of machines to produce 50 tons per week

Steel sleeper press. The steel plate from which the sleeper is to be made will be rolled direct from the ingot to the final plate without re-heating This will be accomplished on the blooming mill and sheet bar and billet mill The plates will be cut by the flying shear of the sheet bar and billet mill in two or three length pieces and automatically placed on cooling beds at the end of the mill. From there, they will be handled by an overhead electric crane to a heating furnace where the plates, after being heated, will be formed into steel sleepers by a hydraulic press.

Roll turning shop. A new roll turning shop is being erected and additional lathes are being secured in order to turn the rolls required by the Company in its existing and proposed mills.

Laboratory. A well-equipped chemical and physical laboratory is attached to the works for testing the raw material and finished products. There is also a Government laboratory in charge of a Government official who tests the steel made by us, for which a Government certificate is required.

Machine shops: structural shops, etc. In addition to the present machine shop, a large new shop containing up-to-date machines is in course of erection and some of the machines are now producing material required for the construc-

tion of the extensions to the plant. In addition, there are shops for pattern makers and carpenters, blacksmiths, locomotive repairs, electrical repairs and structural shops

Power house. The power house contains three turbo-blowers for supplying air to the furnaces in the blast house A volume of 32,000 cubic feet of air, under pressure of 15·5 lbs to the sq. inch, is blown into those receptacles in the course of a minute, and the power absorbed is for a full load 2,250 H. P., for a three-quarter load 1,920 H. P., and for a half load 1,700 H P. The plant consists of two 1,000 kilowatt and one 1,500 kilowatt, 3,000 volt turbo alternators running at a speed of 3,000 revolutions per minute, and three transformers of 1,250 K.V.A. 3,000 to 440 volts and two motor generator sets of 500 kilowatt each.

To supply the necessary power required for the operation of the extensions, it is proposed to instal three 5,000 kilowatt turbo generators (one of which is now in course of erection), one 4,200 kilowatt turbo generator, one 2,000 kilowatt generator, one 2,000 kilowatt mixed pressure turbine, with the necessary transforming equipment to step down from high to low tension. Most of the additional machinery required for generating power is to be erected in a new power house building. The boiler pressure of the plant is 175 lbs. per square inch.

Water supply. The supply of water, not only for the works but also for the large number of persons living in the adjoining township, which has come into existence since the commencement of the works, was at the outset a question of supreme importance to the Directors, but ample provision has been made for all purposes by pumping from the Subernarekha river—a distance of two miles. The water is pumped electrically through pipes 30" in diameter from the river to a very large storage tank at the works.

Subsidiary Industries. Arising from the scheme of extensions with the greatly increased product of the steel works, arrangements have in some cases been almost concluded, and in others negotiations are proceeding, for the establishment of various manufacturing companies in the neighbourhood of Sakchi, in order to take advantage of the close proximity of the steel works from which the raw materials required will be furnished. A list

is given below of the various manufactures it is intended to produce :—

(1) steel tubes and pipes,
(2) tinplate,
(3) enamelware of various descriptions,
(4) railway wagons,
(5) spelter,
(6) wire shapes of various kinds, including fencing wire, nails, etc.
(7) tea machinery,
(8) agricultural tools,
(9) galvanised products,
(10) jute mill machinery,
(11) structural work,
(12) iron and steel castings,
(13) heavy chemicals,
(14) sulphuric acid,
(15) nitric acid,
(16) fertilizers,
(17) explosives,
(18) drugs,
(19) perfumes, etc., etc., etc.

Social welfare work.

The Tata Iron and Steel Co. started operation only in 1912, and though up to now the main efforts of the Company were directed towards overcoming the initial difficulties common to a new steel plant and getting up an efficient organisation, the intellectual and physical well-being of the employees were attended to as far as the circumstances could permit. But now that the Company has been established on a firmer footing, various important welfare schemes have been engaging the mind of the Board of Directors and the Management. We are giving below a summary of the existing institutions at Sakchi for the well-being of its employees and the proposed welfare schemes now under active consideration.

We have a hospital where the Company's employees and outsiders are treated free of charge. The number of patients treated in this hospital for the year ending 31st December 1916 comes to about 154,857, out of which 40 to 45 per cent. were outsiders. This hospital is taken advantage of not only by the employees of the Company,

but also by the inhabitants of some 12 to 15 villages situated within the radius of 4 to 5 miles of the town of Sakchi It has been calculated that the number of patients is drawn from a total population of approximately 60,000 souls. As the accommodation at the present hospital is not sufficient to cope with the increasing number of patients, arrangements have been made for building a new well-equipped hospital on modern lines.

In connection with our present hospital we have a segregation shed, situated at a distance from residential quarters, where patients suffering from infectious diseases are kept We have also a convalescence fund from the interest of which poor employees, who have no money to support themselves during the period of convalescence, are helped. As the want of a convalescent home for our employees is very much felt, arrangements are being made to have one built on the top of the neighbouring hill.

We have three schools at present at Sakchi (*a*) Mrs. Perin Memorial School, (*b*) a night school, and (*c*) a mechanic school The Mrs. Perin Memorial School is a Middle English School. The average number of boys attending this school at present is about 170. This school is wholly supported by the Company. The accommodation in the Mrs Perin Memorial School has been found insufficient to take care of the increasing number of scholars and an annexe has been built, which it is hoped will suffice to meet all requirements for the next few years. A new up-to-date girls school has also been completed and it is hoped will be open before this article appears in print.

In the night school, *chokras* and other employees of the Company, who are desirous of learning English and mathematics, get free tuition every evening for two hours. The number of employees attending the night school is about 65 at present.

In the mechanics' school, promising young boys of the *mistri* class employed at our works are taught elementary mathematics and drawing with a view to make them more efficient in their work. This school is also wholly supported by the Company.

It has also been proposed by the Government of Bihar and Orissa, with the help of this Company, to start a technological college at Sakchi which would specialise in metallurgy and electrical and mechanical engineering, and this proposal is at present under discussion between this Company and the local Government.

Arrangements are also being made to interest the Servants of India Society to start (*a*) primary schools in the surrounding villages

The Production of Sandalwood Oil in India.

By Alfred Chatterton, F.C.G.I., C.I.E.

The recent development in the production of sandalwood oil in Mysore is an interesting example of industrial progress brought about by the war.

Properties and uses of sandalwood.

The sandal tree, *santalum album*, is a small over-green tree which flourishes only over a restricted area of the elevated forests of Southern India and is chiefly found in Mysore, Coorg and the Coimbatore and Salem districts of the Madras Presidency. It also grows, under less favourable conditions, in the Deccan and Gujarat districts of Bombay. From the very earliest times, sandalwood is mentioned in Sanskrit literature and bulked largely in the foreign trade of India, till the advent of European traders in the East and the rapid development of maritime commerce which then ensued. Only the heart wood, which amounts to roughly about one-third the weight of a felled tree, is of value, chiefly on account of the essential oil which it yields. This oil possesses valuable medicinal properties, and is also largely used in perfumery and in the manufacture of very high-grade toilet soaps. The percentage of oil varies in different parts of the tree, ranging from over 7 per cent. in the best roots to about 5 per cent. in the upper part of the trunk. These figures are somewhat larger than those which have hitherto been accepted and are the result of large scale distillations in Bangalore, in the factory which has been established by the Mysore Government. The heart wood is a very close grained and heavy wood and is, to a limited extent, used in the manufacture of small caskets, picture frames and such like articles. It is well adapted for extremely fine wood carving, and the characteristic products of the *Gudigars* of Mysore are well known. Sandalwood is also largely used in religious rites and ceremonies. To be cremated on a sandalwood pyre is a very high distinction and large quantities are annually

consumed by the Parsi community in Bombay in daily worship and to maintain the sacred fires in their temples. Reduced to a very fine paste by grinding in water, sandalwood is smeared on the forehead and over the upper part of the body on ceremonial occasions and, amongst those who can afford it, it is used at other times, as the oil contained in the wood produces a pleasantly stimulating effect on the skin

History of sandalwood trade.

In Mysore and Coorg, all sandal trees belong to the State In the Madras Presidency, private ownership is recognised, but the quantity of wood derived from this source is comparatively small as the bulk of the trees are found in the reserved forests Hitherto, it has been customary for the Forest Departments of the three provinces mentioned to dispose of the sandalwood collected during each year by auction sales held in the months of November and December The quantity sold, the amount realised and the average rate obtained per ton of sandalwood are given on the next page in a table, to which a column has been added showing the value of the sandalwood exported from India as recorded in the Foreign Sea-borne Trade Returns

It is unfortunate that the Sea-borne Trade Returns only furnish values and not weights, but it may be assumed that the values for export are appreciably higher than the auction rates owing to the cost of carriage to the port, the cost of finance and the profits of the merchants. Something more, then, than the difference between the forest revenue and the value of the exports represents the value of a part of the internal consumption of sandalwood in India The other part is derived from private sources and, to an unknown extent, from wood illicitly removed from the State forests. It may be stated with certainty that the local demand for sandalwood exceeded 400 tons and probably was less than 500 tons per annum in the years before 1913 Of late, increasingly large quantities of low-grade wood have been put on the market by private owners, especially in the Deccan, and the high price of East Indian sandalwood has resulted in the importation from Western Australia of a substitute (*Fusanus spicatus*) which yields an essential oil in some respects similar to that derived from the true sandalwood.

After the outbreak of war in 1914, the auction sales held in the month of November proved a complete fiasco and the Mysore

TABLE 1.—*Showing the sales of Sandalwood and the exports each year since 1907-08.*

Year	Mysore State			Coorg.			Madras Presidency			Total amount realised at auction.	Value of Sandal wood exported
	Quantity.	Amount realised	Rate per ton	Quantity sold.	Amount realised	Rate per ton	Quantity sold.	Amount realised.	Rate per ton.		
	Tons	Rs.	Rs.	Tons.	Rs	Rs	Tons.	Rs	Rs	Rs	Rs.
1906-07 . . .	2 388	12,84 955	539	230	1,22,065	542	..	74,454		14,87,584	11,30,880
1907-08	2 430	13,70,257	561	240	1 33,505	557	.	73,214	.	15,84,300	12,07,276
1908-09	2,114	10,52,505	498	207	1 03,377	532	.	87,190	.	12,49 072	10 35,120
1909-10	2,069	8 28,438	498	217	1 02 806	473	..	1,58,355	..	10,02,599	7,46,355
1910-11 . . .	2 469	11,46 321	464	181	82,723	457	..	1 38 160		13,65,209	13,36,005
1911-12	2,363	12,59,301	534	181	93 847	552	..	1 43,048	.	15,02,101	18,29,870
1912-13	2 418	22,67,653	937	185	1 14,930	621	..	2,71,970	.	26 54,521	15,22,935
1913-14	2,147	22,58 343	1,051	194	1 01 690	487	..	1 32,375	.	25,71,145	19,29,390
1914-15	334	3 06 970	918	32	24 142	784	..	1,76,162	.	5 07,281	5 38,774
1915-16	2,010	16,99,657	842	390	2 44 [illegible]	806	..	2,47 250	.	22,91,216	15,36,935
1916-17 . . .	1 347	23,09,451	1,714	229	[illegible]	1 571	404	4 89 165	1,208	31 52,974	16,90,245
1917-18	No sales.			300	5 29 [illegible]	1,763	295	5,23,097	1,778	10,52,638	8,40,657
1918-19 (six months) . .	..	.	..		.		..	.	.		92 693

State, more especially, had to face a very serious reduction in revenue from this source.

An examination of the tabular statement will show that, with the annual sales ranging between 2,500 and 3,000 tons, the rates obtained for wood up till 1911 were in the neighbourhood of Rs 500 a ton. In 1912 and in 1913, prices were forced up to practically double the level of previous years and there is but little doubt that this was mainly due to the keen competition of buyers on behalf of German distillers, who were endeavouring to obtain a monopoly in the business of sandalwood oil distillation. The revival of the demand in 1915-16 was due to the rapid rise in the price of sandalwood oil on the London market and this was greatly stimulated in the following year by heavy buying through neutral countries on behalf of German distillers, who became alarmed at the results of the action, now to be described, which was taken by the Mysore Government.

Distillation: history.

The distillation of sandalwood oil in India has been an indigenous industry from time immemorial; but it has always been carried on by extremely crude processes, which failed to extract all the oil in the wood and involved an inordinate consumption of fuel. No accurate data are available regarding indigenous methods; but it is believed that from 10 to 20 per cent. of the available oil was not recovered and that in the process of distillation as much as 50 tons of firewood were used per ton of sandalwood. For a long time past, the distillation of sandalwood has been prohibited in the Mysore State; but there are a number of distilleries in the Madras Presidency near the borders of Mysore. The industry is, however, chiefly carried on at Kanauj in the United Provinces, where the oil is used in the manufacture of *attars*.

Commencement on a large scale in Mysore.

Soon after the formation of the Department of Industries in Mysore in 1913, the question of starting the distillation of sandalwood was considered; but in the absence of accurate information regarding the phenomenal rise in the price of sandalwood at the previous auction sales, it was deemed inadvisable to interfere with such an important source of revenue. At the end of 1914, the collapse of the demand for sandalwood, however, completely changed the situation and led me to propose the establishment of distilleries in the State to extract the oil. In the preliminary investigations

which were necessary, I was able to obtain very valuable assistance from the staff of the Chemical Department of the Indian Institute of Science and, after a number of experiments, a satisfactory process was devised which yielded oil in quality equal to anything that had previously been produced in Europe or elsewhere. At the end of September 1915, the Mysore Government sanctioned an estimate of a lakh of rupees to establish a small factory to turn out 2,000 pounds of oil per month. A suitable site for the factory was found to the north of Bangalore adjoining the land belonging to the Indian Institute of Science, whose resources in the matter of technical staff and mechanical equipment could, therefore, be readily utilised.

Owing to the war, it was found impossible to obtain either machinery or plant from abroad and from the outset it was recognised that only local resources could be drawn upon. Some plant was obtained from stocks in the country, some purchased second-hand and the rest was manufactured in local workshops such as those belonging to the Indian Aluminium Company of Madras and those attached to the Water Supply Division of the Public Works Department in Bangalore.

The factory started work on the 10th of May 1916 and, between that date and the 31st of October 1918 1,331 tons of wood have been distilled, yielding 132,660 pounds of oil. Soon after the opening of the Bangalore factory, it was decided to extend the scale of operations, so that ultimately all the wood available in the State could be distilled and oil, instead of wood, exported. The Bangalore factory was enlarged as rapidly as possible and its capacity increased from 2,000 to 6,000 pounds a month, whilst a second factory, which it is intended will have an ultimate capacity of 20,000 pounds of oil per month, was started in Mysore. The construction of this latter factory was sufficiently advanced to enable distillation to be started at the end of August 1917, and since that date up till the 31st of October 1918, 782 tons of sandalwood have been distilled, yielding 79,711 pounds of oil.

The time chosen for the inception of this enterprise was extremely favourable. In July 1914, East Indian sandalwood oil was selling in London at 21 shillings a pound; in 1915, it rose to 30 shillings a pound and in 1916, when we first began to place Mysore oil on the London market, it had risen to 40 shillings a pound and ultimately in 1917, it reached the maximum limit of 50 shillings

a pound, at which it has since remained steady. The following extract from the "Perfumery and Essential Oil Record" in an article on "Four years of War Prices" sums up the situation: "Sandalwood Oil Consumption has much grown in the war period, and as stocks sank price increase naturally followed The advent of Mysore distillation has apparently steadied matters, and Southern India appears certain to play a large part in the future supply of the distillate"

Initially, the whole of the sandalwood oil we produced was sent to Europe, but recently, an extensive demand has arisen in America and Japan In 1917-18, the industry was considered to be sufficiently firmly established to abandon the sale of wood by auction in Mysore, but, as will be seen from the tabular statement above, considerable quantities of wood have been sold by auction in Madras and Coorg. Owing to the restrictions on freight, it is believed that the bulk of this wood has not yet left the country As the average yield from sandalwood, including the lower grades, is about 100 pounds of oil per ton of wood, the establishment of distillation in India has resulted in a useful reduction in the demand for shipping facilities as the weight of the oil, when packed, is only about 10 per cent of the weight of the wood from which it is obtained.

The distillation of sandalwood gives employment to a considerable amount of labour and involves the consumption of a large amount of fuel. In practice, over 500 pounds of steam are required to liberate one pound of oil and roughly each ton of sandalwood involves the consumption of 8 tons of wood as fuel Besides steam for the actual distillation work, a considerable amount of power is required in the sandalwood oil factories (1) to break up the wood into such a form that the steam can get at the oil cells, (2) to maintain the necessary circulation of cooling water through the condensers, and (3) for electric lighting, as the factories are run continuously both day and night. In the Mysore State we enjoy the advantage of being able to obtain all the power required from the supply mains in the cities of Bangalore and Mysore, which are connected up with the large hydro-electric station at Sivasamudram. The process of distillation is a continuous one. The factories are shut down only when it is necessary to clean the boilers. The work is carried on by eight-hour shifts, and each shift is in charge of an Indian-trained chemist and, in addition to the men on the

shift, several chemists are employed to supervise the work of purifying and packing the oil. The value of the product renders it essential that extreme care should be exercised at every stage of the process and finally, before any consignment of oil is sent out of the factory, a sample is taken and analysed to ascertain that it complies with the specifications of the British Pharmacopœia. This renders it essential that the control of all work in the factories should be in the hands of graduates in chemistry, engineering or physics, and the number of such men so employed is exceptional for an Indian factory industry.

Sales. By the sale of sandalwood oil in 1916-17, we realised Rs. 7,59,489, whilst in the official year 1917-18, the realizations amounted to Rs. 27,50,422 and in the current year, they are expected to reach even a higher figure. As a setoff against these high prices, the prevalence of war conditions has greatly increased the cost of manufacture, chiefly owing to the rise in the price of fuel and stores, to which must be added the enormous rise in the cost of moving the oil, due to enhancements in railway and sea freights and to the increased cost of marine insurance. Compared with many other essential oils, sandalwood oil has risen in value to but a moderate extent and has approximately kept pace with the depreciation in the value of money. This is largely due to the limitation of the trade demand, owing to the elimination of the very large market which formerly existed in enemy countries, and this restriction has been further increased since the collapse of Russia.

The future outturn of sandalwood is gravely menaced by a disease known as "spike" which first made its appearance about

"Spike." 20 years ago. The external symptoms are a decrease in the size of the leaves and a shortening of the internodes. Every tree attacked, in course of time, dies and attempts to check the disease by uprooting "spiked" trees have entirely failed, though in Mysore alone upwards of 700,000 trees were so dealt with in the years 1903-10. The disease is an extremely obscure one, and so far has entirely baffled investigation. Joint action is now being taken by the provinces interested, but so far the war has greatly interfered with the prosecution of the enquiries. As a sandal tree does not arrive at maturity in less than 40 years, it is essential that means should be found, as early as possible, to protect existing trees from the

risk of infection and as the financial interests involved are very considerable, energetic action is clearly necessary. The tree is a parasite and though the Forest Departments have devoted much careful study to the cultivation of sandal trees, their efforts at reproduction have met with but little success. Now that sandalwood is removed from the list of raw materials exported from the country and the manufactured products have obtained a world-wide reputation, it is necessary that all the problems connected with the industry should be dealt with scientifically, so that the largest possible revenue may be derived from the monopoly which the South of India enjoys in the supply of a drug in almost universal demand. The extraction of the oil is now carried out on modern lines. The therapeutic properties of the oil are under investigation by the medical officers of the Mysore State, and a census is being made of the number of trees growing in the State; and to complete the work of putting the industry on a firm basis, it is necessary to call to our assistance the resources of science to combat the ravages of "spike."

An examination of the figures given in the tabular statement on p. 412 combined with the returns of sales effected by the Mysore factories, clearly indicates the growing importance of the sandal tree and the sandalwood oil industry as a source of revenue to the provinces concerned. From average sales at the auctions of a little over 13 lakhs ten years ago, the realisations increased to 26½ lakhs in 1912-13, and for the last two years the combined sales of wood and oil have reached 39 lakhs under what can only be described as very unfavourable trade conditions.

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